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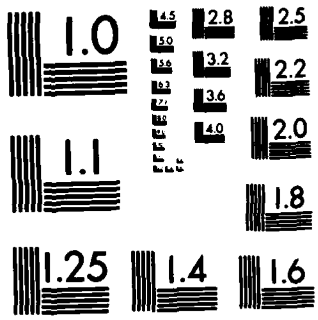

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DEVELOPMENT OF A COMMUNICATION SYSTEM COMPATIBLE WITH CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT

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[illegible]

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P. O. Box 1446
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June 1986

Final Report

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16. Abstract

The U. S. Coast Guard and NASA joined in a project to develop a communications system to operate inside protective suits used in chemical spill response. REMIC Corporation, of Elkhart, Indiana, was awarded the contract by NASA for developing this communication system.

Coast Guard Strike Teams were consulted to determine operational requirements for the communications system. The contractor also studied environmental problems, investigated the special needs and restrictions of the user, and developed possible package configurations. Various options were presented for Coast Guard consideration with a description of each choice's advantages and disadvantages. NASA and the Coast Guard determined that the suit communication system should be built into a separate light-weight low-profile garment which would not interfere with other equipment being worn. A number of microphone and control options were developed to increase the system's flexibility. Although primarly for totally-encapsulating suits, the system was also designed for use with lower level protective clothing or with ordinary attire. Coast Guard marine band frequencies (157 MHz) were selected for the transceivers and repeaters. Engineering models were presented studied, and modified during a series of review meetings. Prototype transceivers and repeators were fabricated and delivered to the Coast Guard. Field tests with the USCG Pacific Strike Team at Hamilton AFB, California demonstrated that the communications system met the special needs of spill response personnel.

This report also provides recommendations for commercially producing the communications system, and establishing operating and training protocols.

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EXECUTIVE SUMMARY

The US Coast Guard joined with the National Aeronautics and Space Administration (NASA) in a project to develop a communications system to operate inside an encapsulated suit - as part of the program to develop a Hazardous Chemical Protection Ensemble (HCPE). REMIC Corporation, of Elkhart, Indiana, was awarded the contract by NASA, for development of this communications system.

The contractor's first activity was to consult with Coast Guard Strike Teams to determine operational requirements for the communications system. The contractor also studied environmental problems, investigated the special needs and restrictions of the user, and investigated possible package configurations. Various options and recommendations were then presented for Coast Guard consideration and selection. The advantages and disadvantages of each choice were described. Following a special design review meeting, NASA and the Coast Guard determined that the HCPE communications system should be built into a separate light-weight garment with low profile so as not to interfere with other equipment being worn. The microphone should be inside the breathing mask but wires must not penetrate the mask. All controls must be inside the suit so as to be preset by user, but the push-to-talk switch should be operated by pushing on the suit wall. The speaker system should not impair the hearing of the user, yet should enable the user to clearly hear transmissions in noisy situations. The antenna should not protrude in a way to present a hazard or catch on objects. The wiring should be mostly within the garment, with the connections to speakers, microphone, antenna or battery, using as few connectors to the radio as possible. Although first consideration is to provide a communications system for use with the HCPE suit, the system should be designed for use also with protective clothing of lower levels, or with ordinary attire. The repeater should transmit on 157.075 MHz and receive on 150.075. Simplex operation should be on 157.075 MHz.

The contractor designed and constructed engineering models to fulfill the general and specific requirements of the Coast Guard. These units were presented, studied, and modified during a series of review meetings, leading to Coast Guard and NASA approval of the design for the prototype HCPE communications system. Eight transceivers and 4 repeaters were then fabricated and delivered to the Coast Guard for testing.

Members of REMIC engineering staff joined with officials of the Coast Guard and NASA in field testing the prototype units at the USCG Pacific Coast Strike Team station, Hamilton AFB, California. The tests, which were conducted using procedures established by the Coast Guard, demonstrated that the communications system developed by this project meets the general requirements and special needs of personnel responding to spills of hazardous chemicals.

This report concludes with recommendations for production of the HCPE communications system, and recommendations are made regarding operating and training protocols.

DEVELOPMENT OF A COMMUNICATION SYSTEM COMPATIBLE WITH CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT.

Table of Contents

I. Introduction.

The Coast Guard is mandated to respond to spills of hazardous chemicals in or near the waters of the United States. In order to provide an adequate response capability, the Coast Guard Office of Research and Development undertook a program in Hazardous Chemical Personnel Protection. Part of the program involved developing a Hazardous Chemical Protection Ensemble (HCPE). The primary component, a fully encapsulated suit, was designed. Preliminary prototypes were fabricated and tested, and production specifications were prepared. Auxiliary components of this ensemble include a recirculating water-based cooling system, a breathing apparatus and a communications system.

No single communications system was found by the Coast Guard to meet all of its requirements in terms of range, operation, and compatibility with other equipment. Particular problems associated with the Coast Guard application were primarily related to packaging. Limited space is available inside the ensemble because of (1) the breathing apparatus which rests on the person's back, (2) the cooling system which is located on the front of the suit, and (3) the need for the user to wear a hardhat or similar protective headgear inside the suit. A manifestation of these limitations is that the communications device be compact and easily operated, preferably "hands-free". The Coast Guard also envisioned that the communications device be usable with protective garments of a lesser level than the HCPE ensemble.

The Coast Guard was aware of a project, sponsored by the National Aeronautics and Space Administration (NASA), in cooperation with the U.S. Fire Administration (USFA), for development of an improved fireground communication system for firefighters. That project, which was conducted in 1982-83 by REMIC Corporation, of Elkhart, Indiana (contract NAS8-34684), confirmed the urgent need for a fireground communication system, identified the desired characteristics for the system, and prepared functional breadboard transceivers to exemplify the system concept. That project demonstrated the feasibility of producing a low cost, reliable, communication device to meet the needs of the fire service.

As a continuation of that earlier work, the Coast Guard joined with NASA in a project to develop a communications system to operate inside an encapsulated suit and meet Coast Guard requirements. The contract for this project (NAS8-36456) was awarded to REMIC Corporation.

II. The Need for a Special Communication System

Background.

The U.S. Coast Guard Strike Teams typically use eight-man groups for responding to hazardous chemical situations. Four of the team members are dressed in protective clothing and perform the on-site clean-up work. The others are in charge of decontamination, as well as coordinating and overseeing the job site.

The job sites are usually confined to an area of not more than 12 to 20 acres. The distance separating the support personnel from the clean-up group is usually 300 yards. Members of the clean-up group are normally in close proximity of each other and are rarely separated by more than 200 feet.

The kind of protective clothing used by the Coast Guard Strike Teams depends upon the degree of potential hazard in each situation. These situations are divided into four levels:

A: Requires HCPE suit and self-contained breathing apparatus;

B: A lighter suit which covers entire body, but not sealed; the same self-contained breathing apparatus is used;

C: Same suit as B, but not with same breathing apparatus; a filter type gas mask is used;

D: Laboratory apron, gloves, boots and face mask (hood).

Only about five percent of the situations are at level A, which requires use of the HCPE suit.

Team members working in the totally enclosed suits have their working time limited, in part, by the air supply which they must carry. Most team members agree that 60 minutes is the maximum time that one would spend working in the HCPE suit. Total suit components, with the breathing apparatus, weigh about 60 pounds.

Present Communications Equipment

The situation described here applies to the Pacific Strike Team, and is considered to be fairly representative of the Coast Guard as a whole. Strike team members have devised a communications system built from equipment that is available commercially. The support personnel use a standard handy-talkie (HT) radio. Team members in suits use the same unit with some accessories to adapt the HT to the suit. The HT transceiver is worn at the waist clipped to one of the straps of the breathing apparatus. A single

earphone, either in an enclosure or in the form of an earplug, is connected to the HT.

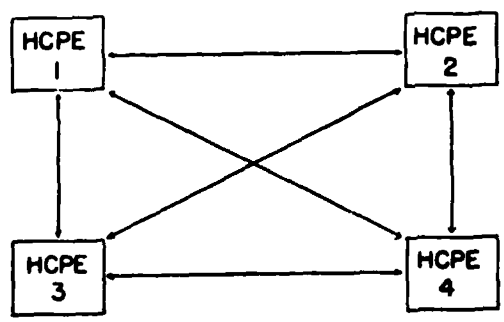
A boom microphone element is inserted into the air exhaust of the respirator mask, or a throat microphone is used. The transmitter is activated by use of a large, remote Push-to-Talk (PTT) button clipped on the harness. The entire system is contained inside the transceiver with Voice-Operated (VOX) transmitter controlling the transmitter activation. This unit is also enclosed totally by the suit.

The HT units in use operate in the marine band (VHF) at 157 MHz. Six channels are available in each HT. The headset transceivers operate on a single channel in the 49 MHz unlicensed frequency assignment band.

The strike team also presently uses a repeater station. The unit is powered either from 120v AC or 12v DC from an on-site vehicle. The unit has two power outputs, the highest power being 25 watts. The repeater uses a magnetic mount for placement on the vehicle.

Two-way radio communications are established using two different techniques. In the direct configuration, all personnel operate on the same radio frequency channel.

DIRECT COMMUNICATIONS

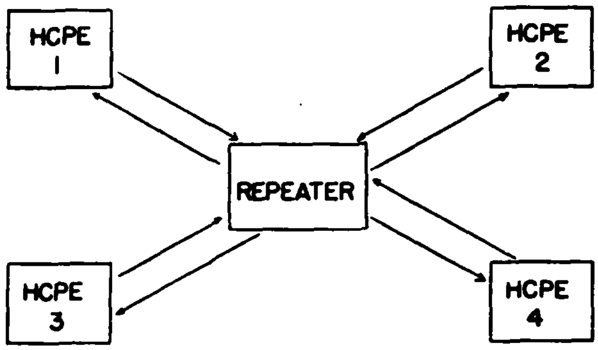


REQUIRES 1 RF CHANNEL

Each team member communicates directly with any other . This configuration is effective as long as all of the personnel are within radio range of each other. The Repeater configuration is used to increase range of penetration by using a repeater as a re-

lay device. In this configuration, the individual users transmit signals to the repeater which re-transmits the message to all other users. Placing a repeater in the appropriate location can greatly increase the reliability of the communications network.

REPEATER COMMUNICATIONS



REQUIRES 2 RF CHANNELS
1 TRANSMIT, 1 RECEIVE

Environmental Problems.

The largest problem imposed by the HCPE is space. The suit components and support systems occupy almost the entire interior volume of the suit. The breathing apparatus is located on the wearer's back. Hoses connect the air tank assembly to the pressure regulator which is worn at waist level hooked to the harness. Another hose connects the regulator to the breathing mask. The exhaust of the mask empties into the suit to cause a slight positive pressure inside the suit. This pressure is regulated by several relief valves.

The cooling system is composed of several major components: a cooling garment, a circulation pump, and a cold water/ice bag. The ice compartment is located on the front of the suit where the ice can be added from the outside without breaking the seal of the suit. The cold water source is connected to the pump via hoses with quick-connect fittings. The pump is hooked to the suit harness at waist level (on the side opposite the regulator) and connected to the cooling garment by another set of hoses and connectors.

Head protection is provided by either a conventional hardhat or a bicycle helmet. The hardhats are modified by removing the brims

so that they do not restrict turning of the head by snagging the interior of the suit. The bicycle helmet's shape allows it to be used without modification.

Other Operating Restrictions.

A number of additional operating restrictions result from the following:

1. Many encapsulating suits have a tight seal between the sleeve and glove. Working gloves may be taped into position on the outside cuffs of the suit sleeves. This prevents most people from retracting their hands from the sleeves once the suit is closed. In that case, adjustment of the equipment controls inside the suit is not possible. This is not a problem with the new Coast Guard Teflon suit.

2. The breathing mask assembly cannot be altered to accommodate a microphone without destroying the mask seal. Microphones now used are either contact type or their placement is not conducive to good pick-up of speech.

3. The combination of exhaust breathing air and perspiration causes a 100% humidity level inside the suit.

4. Harness straps, air and cooling hoses, pose problems for the routing of wiring harnesses, and for the location of communications system components.

5. Suit complexity requires that the communications systems be staged and tested at several intervals during the dress up.

6. The shape of the hood restricts the shape of helmets worn inside the suit.

7. The weight of the suit and its components requires that the communications system be as light as possible.

8. The shape of the suit does not permit easy access "through" the fabric. Any controls that require adjustment through the garment must be physically large to permit their operation.

9. The suit is routinely cleaned or scrubbed with detergent after use.

10. The water circulating pump of the suit cooling system may create a large amount of RF interference. Use of this or other pumps should consider shielding to reduce this problem.

Specific Coast Guard Requests.

The Coast Guard developed a list of desirable characteristics for the HCPE Communications System:

1. A "clear channel" concept should be established (nationwide) for this system. Channels that are not used in one location are frequently in heavy use in others. Since the strike teams are mobile, they must be certain that communications are possible in any area. A total of four channels, two repeat and two direct, should be available.

2. Mounting of the system should be such that it can be adjusted (for some of the functions) from outside of the suit by another team member.

3. The communications system should be designed so that no more than five minutes is required during dress-up to make it fully operational.

4. If the unit is helmet mounted, weight becomes an important factor.

5. It is desirable that the system be easily adaptable to situations where a full HCPE suit is not required. The system should be readily adaptable for use with protective clothing at all levels of chemical response situations.

6. The microphone technology must be such that the transmitted voice is clear and readily understandable. Current contact throat and bone microphones are subject to mis-alignment once the wearer starts to sweat, and they slip out of position.

7. A VOX (hands-free) system is preferred since the PTT system requires that the team member remove his hands from the task to push a button. Their hands are frequently contaminated and this could spread the contamination to other parts of the suit or to the face window area. The VOX must not activate the transmitter on noise created by the breathing apparatus.

8. The system should be intrinsically safe.

9. The repeater system should be totally portable and self-contained. It should have a shoulder strap for transportation. The batteries should last 4 to 5 hours.

10. There should be an optional speaker/amplifier in the suit system so that those not wearing radio systems could hear what those wearing the suits are saying.

11. A minimum of connecting cables should be employed for less risk of snares and tangles. The wiring harness should be removable from the suit in the event that the suit becomes hopelessly contaminated and has to be discarded.

III. Choice of Configurations.

Various communication system configurations were considered in determining the most appropriate packaging to meet the needs of the Coast Guard. The contractor presented the advantages and disadvantages for each configuration and made recommendations for the selection of the final system packaging.

Microphone Design

Regardless of the ultimate transceiver design, it was clear that substantial effort must be made to design a microphone compatible with the breathing masks currently in use. Although several kinds of masks are used, they are all of the same concept although of slightly different construction. Considering that the mask integrity cannot be compromised, the design of the microphone could take one of two forms:

1. A pass-thru connection through the sidewall of the mask could be made, allowing connection of internal components to the transceiver circuitry. This pass-thru would have to be molded into the mask assembly by the manufacturer. The cost of this operation at the production level would be relatively low, requiring slight modification of the production tools to accommodate an insert mold connector. Once the tooling modification is made, the production part cost increase should reflect only the cost of the connector plus a small amount of added labor for the insert molding process. (The mask manufacturers would have to be convinced that this tooling change is both desirable and economically justifiable. This operation probably could not be performed by anyone other than the original mask manufacturer. Should another company make the modification, it would probably have to get recertification of the entire new mask assembly.

2. A thru-the-wall electronic assembly could be designed to transfer the microphone signals through the mask material to a pick-up mounted outside the mask assembly. This is not a new concept, although review of the several existing devices reveals serious drawbacks. Some units add a great deal of electrical noise to the microphone signal. Others are very subject to AC (60 Hz) hum from power wires, causing speech distortion. In all cases, an electronic circuit must be placed inside the mask along with a battery to power the internal circuitry. The internal battery becomes another maintenance problem since the entire communications system fails if the internal battery fails. In addition, the cost of this micro-electronics package is relatively high due to its complexity and its operating environment (100% humidity from breath

and perspiration). The cost of this component would be incurred on each mask assembly (in addition to the cost of the microphone and transceiver systems).

Transceiver Configuration.

Three clear options were considered for the transceiver configuration.

First Option for Transceiver

The first of the options is a component type system, using several main sub-systems. Sub-system #1 contains the microphone pick-up elements and electronics, probably mask-mounted. Sub-system #2 contains the audio reproduction system for the receiver. The speaker elements could be mounted in the suit, in earphones, in a helmet or on the mask. Sub-system #3 contains the wiring harness. This harness will connect the various sub-systems together using moisture-proof connectors mounted at convenient places on the suit and mask. The harness would be attached to the inside of the suit in a manner that would allow its replacement but that would be secure enough to restrain it from coming loose inside the suit during use. The harness would penetrate the suit with a suitable connector to interface with the transceiver package. The antenna would be included with the harness and be located on the upper portion of the suit.

Sub-system #4 would contain the transceiver and control circuitry. This unit would be designed to mount on the outside of the suit in an area that is free from suit components. A likely location would be on the rear of the suit just below shoulder level on the side opposite the pressure relief valve assembly. The transceiver case would also contain the battery pack assembly. It would be waterproof. All connections to this sub-system would be via a single connector allowing easy placement of the unit. The controls of the system would be in the form of a membrane switch touch panel with large switch areas that could be operated by gloved hands (not those of the wearer of the unit, due to the rear mounted location). Controls would be simplified with a minimum of user operations.

Advantages of this type of system are:

* The transceiver unit could be easily adjusted from outside of the suit by a team member. If the operation of the unit required changing (volume adjustment, channel change, etc.) the change could be done by a team member without opening the suit.

* The entire transceiver could be replaced in the event that it was damaged or became defective.

* The weight of the communications system would be distributed evenly so as not to add to the existing weight burden.

* The transceiver could easily be detached for cleaning or maintenance.

* The modular approach allows the communications system to be field serviced easily.

Disadvantages of this option are:

* Several connections to the various sub-systems would be made and each would be a potential trouble spot.

* This system would not be easily adaptable to the protective clothing and equipment worn at Levels B, C and D operations, since several components would be part of the HCPE suit. An alternate configuration would have to be designed and stocked to accommodate the other suiting scenarios.

Second Option for Transceiver

Option Two is a system that contains relatively few major components. The microphone sub-system would remain the same as described for Option One. The most significant difference lies in the location of the transceiver and control circuitry. In this case, these components would be adapted to fit into or onto the protective helmet. The receiver audio reproduction components would also be part of the helmet. Control locations would utilize the same technology as previously described, except that they would be located on the anterior of the helmet for easy operation. The battery pack assembly would be mounted in a small separate enclosure and be connected to the helmet by a detachable cord. The pack would be clipped to the suit harness. This would be done to keep the weight of the unit (which is due mostly to batteries) to a minimum on the head. The antenna would be integrated into the helmet.

Advantages of this system are:

* The system is nearly self-contained (with the exception of the battery pack) which allows it to be used in a wide variety of applications. The unit could be used without the breather (if not required) by substituting a different type of microphone.

* There are relatively few connecting cables. One is very short, from the helmet to the mask, the other is to the battery pack.

* The battery pack can be separated from the transceiver.

Disadvantages to this system are:

* There are significant problems with designing an electronic assembly into an already existing product that is is not under absolute control of the electronics manufacturer. If the helmet maker were to discontinue the particular model, or change the design of that model, the electronics manufacturer would have to redesign accordingly. The estimated total number of production units bears heavily on whether the helmet manufacturer would retain this particular product in his line if the the communications system was the only use for the helmet.

* The assembly would require more segregated components as there is usually very little extra continuous room inside of a helmet. The control assembly and transceiver would have to be shielded from the antenna radiation for reliable operation (an added manufacturing cost).

* Some compromise to the receiver audio system might result from size constraints.

* Once the suit was closed, the unit would not be accessible for change of control function. Some controls could be mounted on the front of the helmet so that they could be seen and operated through the faceplate, but with the possibility of soiling the faceplate.

Third Option for Transceiver

The third option is a communications system designed into a separate garment which would enclose all of the transceiver components except the microphone sub-system (previously described). The garment design would be such that it would not add unnecessary straps to the existing hardware of the suit. The major portion of the weight and the controls would probably be located high on the center of the chest where they would not in any way restrict the use of the arms. This system would imply the same type of sealed control panels as described in Option One.

Advantages:

* Since the transceiver circuitry would be in one enclosure, very few exposed connecting cables would be required to structure the system. A cable to the microphone, another to the audio reproduction, and possibly one to the antenna, are all that would be needed. These could be made into a single multi-conductor cable.

* The entire unit would be field replaceable if the unit

became defective while in use.

* The transceiver sub-system would take a minimum amount of time during dress-up due to the limited number of connections required and because of the garment format.

* This configuration could be used with any type or respirator combination, or without any respirator or suit, simply by using an optional microphone sub-system.

* The system would require the fewest adjustments or least re-configuration upon arrival at the site.

* The location of components in this option would be such that it would not interfere with manual tasks; and the possibility of damage to the system by the user becoming tangled in the cables would be low (due to the placement and the number of cables).

* This design would have a higher predicted reliability due to the minimum numbers of exposed sub-system components and connecting cables.

Disadvantages:

* This design dictates that an additional garment or assembly be worn.

* The tooling for this type of product is more expensive due to its complex construction (waterproof, heat resistant, etc.). This design is not easily made in prototype form.

* The design requires study of the various respirator configurations to ensure that the end product is compatible with all these units.

* The antenna sub-system might have to be external to the garment due to the RF shadow imposed by the air tank. An antenna remotely located imposes added mechanical and electrical complications.

* The controls, which would in an ideal location otherwise, would not be accessible inside of the HCPE suit. Their location would probably be covered in the cooling system ice tank.

Frequency Considerations.

Communication systems now used by USCG National Strike Force groups are in two services: marine or unlicensed. Strike Force members have indicated that they have no preference in the actual operating frequency as long as it is on a "clear channel".

The marine service at 150 MHz is available to the general public

as well as to commercial vessels. The Coast Guard itself uses numerous channels for port frequencies, emergency, and ship to ship communications. The loading of these channels is variable and unpredictable. The public access to these channels can create a "loaded" channel in a matter of minutes. In addition, the port frequencies are not fixed throughout the nation, so those channels are not available on a nationwide basis.

Power output in the marine band is limited to 25 watts. This amount of power has the potential to travel many miles, especially over open water. The potential for on-channel interference is increased from stations operating legally at some distance from the Coast Guard work site. Under these circumstances, securing one of these channels for continuous use would amount to a matter of voluntary public courtesy.

The FCC unlicensed service, at 49 MHz, was conceived for short range communications. These channels are used for all types of unlicensed services: cordless telephones, hobby walkie-talkie sets, security systems, etc. FCC rules dictate the strength of the signal that can be created by these devices. This power level is such that the signals travel about 1/4 mile under average conditions. The restricted range of this class of unit allows the frequencies to be "clear" if some distance separates the users of the units. In urban areas, however, the cordless telephone population causes some interference. This class of FCC service does not permit the use of repeaters (all units must be under local control).

It became evident from earlier REMIC research that "clear" channel communications are required if the Fireground Radio System is to be effective. The same applies to the proposed communications system for the Coast Guard National Strike Force when responding to spills of toxic substances. A group of frequencies should be set aside by the FCC for emergency communications. The frequenies should be the same nationwide and should have the following restrictions:

1. Low power portable units only; power output less than 5 watts.

2. No base or mobile stations allowed.

3. Channels to be used for on-site activity only; no dispatch or routine traffic allowed.

4. Technical limitations requiring that all transceivers employ identical transmission and reception characteristics (and squelch configurations) so that the transceivers are compatible nationwide.

5. Six channels available.

If this type of Emergency Service Frequency allocation were put in

place, on-site communications problems resulting from interference and frequency mismatch would be eliminated. This matter deserves the combined and coordinated efforts of all interested agencies in the presentation and justification to the FCC. The need for this service is clear and desirable if emergency communications are to be effective.

Repeater Design.

The design of the repeater should be based on these guidelines:

1. Must be self-contained and self-powered.

2. Must be small and light enough to carry, preferably by a shoulder strap.

3. Use of the repeater should extend the range of the mobile unit to one mile.

4. Should operate 4 to 5 hours (at 30% transmit duty cycle) from its internal batteries.

5. Should have a minimum of controls and be easy to set up.

6. A local microphone and a local speaker should be options, which would permit the repeater station to function as a base station.

7. Connection to a remote antenna for extended range operations should be easily accomplished.

Three elements were seen as major determinants for the size and weight of the repeater: the battery, the duplexer, and the internal shielding components. In order to keep size and weight down, a power output of 5 watts was selected. This output was considered sufficient to provide the desired performance. The internal batteries would be recharged from an external recharging circuit. They would be designed for field replacement. If long periods of operation are contemplated, the unit should be powered from an external 12 volt DC source.

Metal was proposed as the case material to provide durability and to shield the internal circuitry from the antenna. The case integrity should be such that the unit is splashproof, not waterproof or submersion-proof. This type of protection would be adequate for field operation in the rain. Sealed bulkhead type connectors would be used for termination or connecting cables and for the antenna connection.

IV. Development of the Selected Configuration Design.

Based upon the options and suggestions (See preceding Section of this report) presented by the contractor, at a special design review meeting, NASA and the Coast Guard determined the design of the communications system for use with chemical protective clothing. Decisions from that design review were provided to the contractor as follows:

> "Microphone Design: The microphone should be inside the breathing mask, but wires must not penetrate the mask. The microphone system must be designed so that NIOSH certification is not voided in any way."
>
> "System Configuration: The communications system should be built into a separate garment (option 3). The system must be lightweight, low profile and not interfere with the other equipment being worn."
>
> "Other Controls: Suit penetration is completely undesirable. All radio controls must be inside the suit and preset by the user. The push-to-talk switch should be designed to be operated by pushing on the suit wall. Any controls that would require adjustment by the user can only be adjusted by a pushing action."
>
> "Speaker/Headset: The speaker system should be designed such that the hearing of the user is not impaired. The location of the speaker should enable the user to clearly hear transmissions in noisy environments."
>
> "Antenna: The antenna should be mounted to allow maximum communications range. It should not protrude in such a manner as to present a hazard or catch on objects."
>
> "Wiring: The majority of the wiring should be integral within the garment. Connections to the speakers, mic, antenna, or battery should use as few connectors to the radio as possible. Wiring that leaves the garment containing the electronics should proceed in a linear manner to the rest of the parts of the system."
>
> "Frequencies: ... use of other than the present (Coast Guard) frequencies would be very difficult. The repeater should transmit on 157.075 MHz and receive on 150.075 MHz. Simplex operation should be on 157.075 MHz. The 161.675 MHz half channel 81 is no longer available for use."

V. Development of the Breadboard Prototypes

Upon receipt from NASA and the Coast Guard of the design decisions development work was started on the breadboards for the three separate units that comprise the HCPE communications system; the microphone system, the HCPE transceiver and the repeater station.

The breadboards consisted of hand wired electrical circuitry to prove design integrity. The breadboards also included hand built physical mock-ups of the units. The mock-ups were presented to the Coast Guard at the September 1985 review meeting for comments and modifications.

Each of the HCPE breadboard units are discussed separately.

Microphone Options

1. Mask Microphone System

Concept: The REMIC RF microphone system permits the passage of an audio signal through a non-metallic barrier without affecting the integrity of the barrier in any way.

Application: One of the main uses for the RF microphone system is to provide a communications link through the barrier imposed by a breathing mask (SCBA). This type of mask operates with an airtight seal around the face of the wearer so that none of the air outside of the breathing chamber can be inhaled by the wearer. This type of physical arrangement likewise does not allow air from the inside of the breathing chamber to reach the outside of the mask unless it passes through a check valve system. The construction of the mask makes the wearer's speech inaudible or muffled.

Attempts have been made to solve this communications problem by passing microphone cables through the rubber membrane material of the mask. This solution is not acceptable as the air tight integrity of the mask cannot be guaranteed. Mask manufacturers will not honor claims on any equipment that has been modified in this manner. Several other pass-through systems have been certified, however, these cannot be retrofitted to existing masks in the field. After-market products using magnetic induction (transformer action) principles have been offered but have several disadvantages among which are:

1. Hum or noise in the signal.

2. Large size.

3. Require a battery powered circuit inside the mask.

These limitations offer serious problems to the users of these

microphone devices. The hum or noise present in the signal can cause serious problems in understanding speech that is already distorted by the wearing of the mask itself. Large component size limits the placement of the microphone to an area that might not be optimized for the best speech reproduction or pick-up. Many problems result from the internal (to the mask) battery location. Breathing equipment and masks are usually used in situations of life-threatening complexity. The wearer cannot be assumed to be mindful of the battery condition of his mask microphone system at all times - especially at the conclusion of his tasks. Forgetting to turn off or recharge the internal mask microphone system will deplete the batteries and render the device useless the next time pts use is attempted. This is further aggravated by the lack of availability of the special batteries typically used in these systems.

The REMIC RF microphone system addresses all of the above-mentioned deficiencies. Micro-power circuitry coupled with RF technology permits a system to be built with the following advantages:

1. Small size internal circuitry.
2. High quality audio reproduction.
3. No internal batteries or switches.
4. Easy installation on most commercial masks.
5. Available with attachments to interface to two-way radios or amplifier/speaker unit.

The RF microphone system is composed of two main component parts: the drive assembly and the responder assembly. The driver circuit assembly is contained in the control circuit housing. Power is supplied by the transceiver battery. A small RF coil is then affixed to the outside of the mask, usually on the facepiece where it will not affect vision. The responder is mounted wherever space permits on the inside of the mask. The RF coil of the responder is mounted to the facepiece opposite to the outside RF coil. The microphone is then located where it will pick up speech in the clearest manner. Connections between the mask microphone system and the transceiver are via a simple connector. The inline connector permits the mask system to be separated from the transceiver vest so that the mask can be easily stored. The responder circuitry is fully encapsulated so that the mask can be cleaned without the need to remove any internal component.

2. Throat Microphone

A contact type throat microphone will be provided to accommodate extreme high noise situations, or dress configurations where the mask is not used. Connection to the transceiver vest will be via the inline microphone connector.

3. Hand-held Microphone:

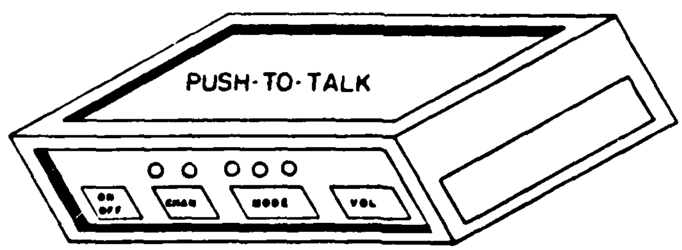
A PTT hand-held microphone will be provided for those personnel who are not required to dress in protective clothing. Connection will be via the inline connector.

The HCPE Transceiver

The transceiver design is based on Coast Guard recommendations and the design goals expressed in the Third Option system.

Physical Configuration: The transceiver, control circuitry, RF microphone circuitry, battery power source and speakers are designed to fit into a vest-like garment. This configuration reduces the number of external devices and exposed wiring. The only external system components are the antenna and antenna mounting and the microphone element.

The unit is arranged so that all control functions could be actuated by single push type switches. The controls are limited to channel selection, power on/off, volume level, and mode selection. The use of this type of control allows completely sealed membrane switches to be used. The controls are mounted on the side of the control chassis so that they are not subject to accidental actuation.



Sketch of Transceiver Controls

The vest also allows the receiver loudspeakers to be mounted internal to the system eliminating the need for earphones or earplugs.

For breadboard purposes, the vest was constructed from canvas

material with stitched seams. This construction allows modifications to be easily performed and required no tooling.

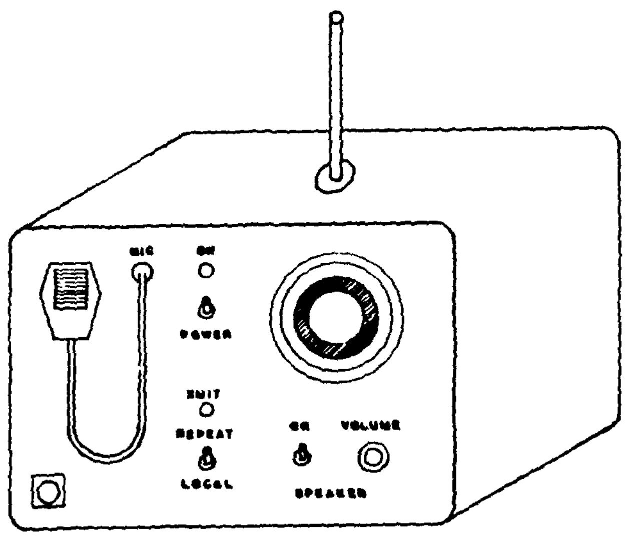
TRANSCEIVER SYSTEM PRELIMINARY SPECIFICATIONS

Housing:	Self-contained vest
Weight:	
Size:	One size fits all
Environmental rating:	Splash-proof
Power requirement:	Internal rechargeable battery
Duty cycle:	2 hours (10% transmit; 10% receive; 80% standby)
Battery recharge:	12 to 16 hours
Antenna type:	Flexible, rubber coated
Microphone type:	RF mask mic PTT hand-held Throat (contact) type
Transmitter power output:	2 watts
Transmitter frequency:	157.075 MHz (DIRECT mode) 150.980 MHz (REPEATER mode)
Receiver frequency:	157.075 MHz
Audio power output:	0.5 watts
Speaker type:	Mylar cone, two units
Electronic specifications:	Per FCC & EIA

HCPE Repeater

The breadboard design of the repeater station was based on Coast Guard recommendations (see Section III). The electrical design of the unit was based on integrating commercially available system components into the physical configuration desired. Special electronic designs were completed for the control circuitry, battery charging circuitry and front panel control functions.

The repeater was designed to be used as a base station command post. In this mode of operation, a local (non-repeat) mode of operation is available. Communications from the command post were via a hand-held PTT microphone.



Sketch of HCPE Repeater

REPEATER STATION PRELIMINARY SPECIFICATIONS

Housing:	Aluminum
Size:	
Weight:	
Environmental rating:	Splash-proof; weather resistant
Power requirements:	110 VAC external power supply 12 VDC: 1.5A 24 VDC: 1.5A Internal sealed battery.
Duty cycle:	Continuous from remote power 4 hours minimum from internal battery
Battery recharge:	Automatic using 110 VAC supply
Antenna type:	Flexible, rubber coated, connector mounted Remote vehicular or base station
Microphone:	Noise cancelling with PTT switch Headset/boom microphone with PTT switch
Speaker:	Reflex horn type, waterproof
Transmitter power output:	4 watts
Transmitter frequency:	157.075 MHz
Receiver frequency:	150.980 MHz
Audio power output:	4 watts

* * *

The physical mock-ups of the HCPE transceiver vest and the HCPE repeater station, described here, were presented to the Coast Guard for comment and review. The electronic breadboards of the control system and mask microphone option were also demonstrated Suggestions and input from this review meeting were factored into design of the field test units.

VI. Construction of Field Usable Prototypes

No unusual problems were incurred in building the field test prototypes. The construction methods and materials used were chosen to allow easy modifications to the units. The choice of materials was also governed by cost constraints. The scope of the contract did not allow any part of the system to be tooled, so hand production methods were used throughout. The hand-built models did not permit testing for FCC parameters, environmental testing, drop testing or testing for intrinsic safety. These tests are reserved for tooled, production units.

1. Microphones

   a. Mask microphone system: The circuitry for the mask microphone system was refined and miniaturized. The driver circuitry was integrated on the same printed circuit board that contained the transceiver control circuitry. The driver and responder RF coils were also miniaturized and encapsulated in an epoxy based material to waterproof them. The responder circuitry was also encapsulated for waterproofing purposes. A small electret microphone was provided and equipped with an external "wind sock" to improve speech response. A set of responder elements was mounted into a breathing mask assembly and tested for audio response and output. The audio frequency response of the system was adjusted to provide the clearest reproduction of speech. Eight sets of prototypes of the mask microphone were assembled and tested.

   b. Throat microphone: The standard REMIC throat microphone was equipped with the proper inline connector for use with the HCPE transceiver vest.

   c. Hand-held PTT microphone: A standard PTT microphone was equipped with the proper inline connector.

   d. Boom microphone: At the suggestion of the Coast Guard, an over-the-head boom microphone was provided. This small size microphone could be used by personnel not required to wear protective clothing or under some forms of protective headgear. The boom microphone may also be used with breathing apparatus masks equipped with a speaking diaphragm. In this configuration, the microphone is taped in front of the speaking diaphragm for voice pick-up.

2. HCPE Vest Transceivers

   a. Radio transceivers were obtained and modified to operate on the Coast Guard assigned frequencies. The transceivers were also modified to operate with the custom control circuitry. Specifications for the transceivers and control functions are fully described in the

operator's manual (see Appendix B).

b. A custom control circuit was developed. This circuitry receives inputs from the keypad switch panel and controls the operation of the transceiver. A memory feature was added so that all of the control settings could be instantly recalled without a lengthy set-up procedure. The original design concept included a PTT switch on the front of the transceiver vest. This design was altered when it became apparent that the switch would be subject to accidental actuation from pressure imposed by the HCPE suit and its accessories. A remote PTT switch was designed to connect to the accessory jack on the transceiver. The PTT switch will be mounted using a belt clip to a strap on the interior of the HCPE suit where it is easily actuated by the operator.

c. A microphone connector assembly was designed that permitted use of any of the microphone options with no adjustment of the transceiver controls. Audio equalizing components were mounted in the microphone connectors to microphone types.

d. An antenna mounting assembly was designed to provide attachment of the antenna to either a standard hardhat or other helmet. The antenna clip requires no modification to the headgear.

e. The vest garment was designed to house all of the system components with the exception of the antenna and microphone. The components were mounted in such a way that the vest was balanced and was worn high on the chest. A system of straps was designed to secure the unit around the chest (if required) and to attach it to the ring of the SCBA assembly. The canvas construction protected the electronic components and was considered splashproof (not waterproof) which was adequate for on-site testing.

f. A total of eight vest transceivers were built and tested for purposes of the on-site field evaluation.

3. <u>HCPE Repeater</u>

a. Major radio system components were obtained and modified to operate on the specified Coast Guard frequencies.

b. A custom control circuit was designed to provide battery charging functions and repeater control functions.

c. The repeaters were assembled in portable cases. The cases were of welded construction with gasketed panels to permit operation in the rain and to withstand decontamination procedures. Sealed switches and connectors were used on exposed surfaces. A waterproof reflex

speaker was provided. The units were self-contained and equipped with storage areas for the PTT microphone and the antenna. The design was targeted for ease of set-up and operation.

d. A total of 4 repeater stations were assembled for on-site testing and evaluation. One of the repeaters was modified (at the request of the Coast Guard) with a power amplifier for 20 watts output. The unit was to be evaluated against the 5 watt units for penetration in critical communications situations.

VII. Evaluation of the Prototypes

A. Test Plan Procedures

As specified in Task #5 of the Statement of Work for this project, REMIC reviewed the test plan prepared by the Research Triangle Institute (RTI)**, furnished by the Government, and offered the following analysis and observations.

1. REMIC agrees that the basic Federal Communications Commission (FCC) and Electrical Institute of America (EIA) specifications should be applicable to the HCPE communications system without major modification. There is agreement also that the units should be intrinsically safe. However, the scope of the contract is limited to producing units to demonstrate the desired functional characteristics. FCC approval and intrinsic safety cannot be completed until the units are tooled, production units.

2. Microphone Alternatives. Regarding microphone technologies, choice of microphone type should not be limited to one particular technology. Contact type (throat) are useful, despite user problems, in areas of high noise. The hand-held microphone with manual push-to-talk (PTT) provides the best communications alternative when it can be used safely and without interrupting required tasks.

   Also, consideration must be given to the mode of transmitter activation - manual or automatic. While the automatic mode, VOX (voice operated transmitter), is most appealing, it has some inherent disadvantages that must be recognized:

   a. VOX circuitry cannot distinguish between meaningful dialog and spurious noises. This means that EVERY sound will cause the transmitter to be activated: grunts, groans, coughs, explitives, etc. These spurious transmissions are, at the very least, a concern as valuable battery capacity is expended in their transmission.

   b. Vital communications between two units may be interrupted by the spurious transmissions as described above. In radio communications, two transmitters cannot simply share a single radio frequency. If one transmitter is being used, and a second is turned on, the result will be garbled reception on the part of the listener. Again, battery capacity will be expended if messages must be repeated due to spurious interruptions.

**The test plan, "Firefighters' Communication Transceiver Test Plan", by Robert J. Wallace, Research Triangle Institute, dated May 24, 1984 (rev. July 18, 1984), was prepared for NASA per contract NAS 8-35816. It is reproduced as Appendix A of this report.

c. VOX systems are most efficient where the number of persons in the communications network is small (three or four) and they are adequately trained in using the equipment. Larger numbers of persons, or those not well trained should communicate using the push-to-talk (PTT) mode of operations.

d. All VOX systems have inherent delays which the users must recognize and understand so that the communications network is efficient at transmitting messages.

The first delay is that of transmitter turn-on. A finite time is required from the instant the person starts to speak to the time that the transmitter is at full power and faithfully repeating the message. This turn-on delay usually results in the first few syllables of the first word of each transmission being "lost". The operators of VOX equipment must develop a protocol in their speech so that the first word spoken is not critical to their message. This will insure that the important part of the message is received in its entirety.

The second delay is designed to prevent the transmitter from being de-activated by the slight pauses in normal speech. This delay is designed to be 1/2 second. Operators of VOX equipment must realize that this delay will be present at the conclusion of their message. Those responding to the message must wait until the first unit's transmitter has turned off before making a response. Responding without waiting for the turn-off delay to expire will result in the first unit not hearing all of the message (his unit will still be transmitting, not receiving). Units should wait before responding to insure that all parties are capable of receiving transmissions.

e. A transceiver can become "locked" in the transmit mode if the user enters an area with extremely high noise or if the microphone shifts from its original position and is allowed to pick up incident noise. The user of his unit may not be aware of this condition and that any problem exists. The result of this condition will render the problems associated with the operation of two transmitters as described above.

Most problems associated with VOX systems can be overcome by adequate training and a thorough understanding of the nature of the radio equipment. Practice drills should be held to acquaint all persons in the communication network with the protocol required to operate the network efficiently. It should be noted that in times of emergency or high stress, the protocol of a VOX system might be cumbersome to use in which case a push-to-talk (PTT) mode of operations should be used if possible.

Operators of Fireground Communications systems are encouraged to explore all microphone alternatives and select the type dictated by the conditions and demands of their particular communications network.

3. Controlled Laboratory Testing of the Device:

The breadboard devices furnished for evaluation are not tooled samples. In this regard, major components of the devices are "hand-made", that is, they were not mass produced by machines with manufacturing accuracy. The fit of these components is adequate for the field testing of the unit, however, inadequate for certain of the laboratory test procedures. These are:

a. Any mechanical test which subjects the device to shock or vibration.

b. Any environmental test for waterproofing, salt spray, etc.

c. Drop testing.

The electronic circuitry of these units was designed according to the references cited in the test plan. Again, for reasons of "hand-made" construction techniques, some variations in certain parameters might be found. These variations will be corrected in the final tooled product. FCC compliance testing requires the testing of mass production type units rather than engineering prototypes. FCC testing will be completed upon completion of mass production units.

4. Testing of Intrinsic Electrical Safety

As detailed above, intrinsic safety certification is granted on mass production products rather than engineering prototypes. Production tooling will be required before the unit can be submitted for this type of testing. Included will be the tooling of the rechargeable battery pack. No statement is made regarding compliance to intrinsic safety standards with regard to the engineering prototype units.

5. Operational Testing Critical Issues

REMIC is in basic agreement with the proposed test plan. The following exceptions and comments should be considered in reation to mission performance:

a. HCPE transceiver systems are not designed for sidetone because loudspeaker operation rather than headset operation is planned. Sidetone is applicable <u>only</u> when earphones are used. Sidetone is actually a portion of the users voice signal which is sent to his earphones as

as a verification that his transmitter is operating. The HCPE transceiver uses loudspeakers, rather than earphones so sidetone is not necessary.

b. HCPE transceivers operate on VHF frequencies selected by the US Coast Guard. Two frequencies were furnished for testing: 157.075 MHz and 150.980 MHz. The RTI test plan was written for a system which was to operate in the 450 MHz VHF band. The RTI plan was not revised for the HCPE project.

Tests required for the categories of Waterproof, Heat and Smoke resistance, Shock and Vibration should NOT be performed on engineering prototype units. These tests should only be performed on mass production, tooled units.

6. Field Tests of the Ensemble Communication System

The field test plan should be slightly modified. The test plan communications script should be adapted for requirements of a VOX protocol communications system. The test plan script as it exists will predictably put a VOX system at a clear disadvantage in score results. The script modifications should include changes to accommodate the turn-on and turn-off delays inherent in VOX systems.

7. Currently Available Ear Microphone Products

An analysis of the currently available ear type microphone products leads to several concerns that must be factored in the use of this microphone technology.

a. The existing products cannot be used with a VOX system. Future generations of this product in relation to VOX systems should be evaluated as to operational adjustments.

b. A concern for the sanitation of the device transducer should be factored unless the device is dedicated to one individual.

c. The transducer typically has poor rejection of incident sound striking the rear of the unit. This could impose the requirement of wearing a noise protector type headgear over the ear transducer when operating in high noise areas.

d. The loss of "natural" hearing in one ear (due to the transducer) might cause concern among wearers who rely on their binaural hearing in the performance of their tasks. Covering the ear (as above) with an ear protector accentuates this problem.

The ear microphone also requires an external preamplifier/equalizer and battery source in its operation. If this type of device is to be used, this circuitry should be integrated into the communications transceiver so that additional external wiring and devices will not further encumber the operator of the communications ensemble.

Evaluation of the Prototypes

B. Field Tests

The HCPE communications system was field tested (with the cooperation of the Coast Guard Pacific Strike Team) at Hamilton AFB, California. The units were evaluated using procedures developed and supplied by the Coast Guard.

Procedure:

A briefing was held to acquaint the test participants with the results of the transceiver and repeater design program. The HCPE transceiver was demonstrated and discussed in detail. The operation of the control circuits, antenna support system, microphone options, PTT switch and battery charger were demonstrated. The HCPE repeater was also discussed and demonstrated. The donning of the HCPE transceiver was also demonstrated. A question and answer period relating to the operation and features of the HCPE communications system followed.

The briefing included an operational test of the HCPE transceivers during which several members of the strike team "suited up" and operated the units. The informal testing included the operation of the HCPE transceivers in a high noise environment simulated by the operation of both diesel and gasoline powered fork lift trucks. The informal testing also included a range test and a penetration test for both the HCPE transceivers and the HCPE repeaters. These tests were performed by increasing the physical distance between users and objectively judging the quality of the resulting communications. The testing also measured the penetration capabilities of the system by requiring that one of the team users position himself in a situation known to cause communication problems. These situations included entering metal buildings and structures, walking behind dense concrete buildings, and working near metal objects such as tanks and drums. The repeater was also tested.

The test session was followed by an analytical session relating to the results of these tests and some suggestions from the Strike Team. In response to these suggestions, REMIC modified the vox hang-time on all of the transceivers so that they switched more quickly from transmit to receive, modified the gain and frequency response of the throat microphones for clearer voice transmission, modified two Motorola PTT switches to work with the HCPE transceivers, and built a prototype throat microphone using the band assembly from a David Clark throat microphone and the capsule from one of the standard REMIC throat microphones.

A second more structured test session was configured. The CG Strike Team members set up an exercise in one of the Hamilton AFB hangars. The test scenario included tasks and situations to

evaluate the HCPE transceivers when worn with various levels of protective gear. These included the new HCPE suit, an older rubber suit, and several types of disposable garments. All of the different microphone options (except the PTT hand microphone) were tested. Both the PTT and VOX modes of operation were used. A second set of exercises was staged to use the HCPE repeater and to test the HCPE transceivers with another group of Strike Team members. Participants in these tests were required to complete the Coast Guard evaluation form with their observations.

A de-briefing was held at the conclusion of the exercises to discuss the results of the tests and to take comments and answer questions.

Field evaluation test results:

1. Form factor - the vest (garment) approach to transceiver packaging was universally accepted. All Coast Guard members that used the transceivers felt that they were less encumbered by location of the communications package (on their body) and felt that the minimum number of connecting cords made dressing and operating the unit easier and more reliable. The time required to don and doff the transceiver was primarily spent in attaching the system elements (microphone option, antenna, PTT switch). The use of locking cable connectors would have eliminated time spent securing and taping connections.

2. Audio reproduction system: The sound quality reproduced by the speaker system was clear and easy to understand. The use of speakers instead of earphones provided the users with the ability to hear important ambient sounds without restriction while still hearing the radio communications. The audio system performed well when the transceiver was worn inside the suit. The results were less satisfactory when the unit was worn with level B & C protective clothing. In these suits, the transceivers are worn under clothing which does not allow the sound from the speakers to propagate freely. The reduced receiver audio levels caused problems with communications when the personnel were in proximity to heavy equipment (fork trucks) or in high ambient noise. Those participating in the testing felt that the use of speakers (instead of earphones) allowed other personnel that would not normally be assigned a transceiver to monitor the communications.

3. Range: The range was far in excess of requirements. All range tests indicated that no communications problems were experienced from either physical separation or the barriers from either physical separation or the barriers from either physical separation or the barriers imposed by metal or concrete structures. No additional problems were found from interference sources (fork lifts) or from working in proximity to metal drums or barrels.

4. Antenna system: Easy to use, no problems were experienced in attaching the antenna to either a hard hat or bicycle helmet. When worn inside of a suit, the antenna stayed in place.

5. Control system: No problems were experienced with the operations of the controls. Coast Guard personnel felt that they were easy to understand and use.

6. Mask microphone option: The mask microphone system was installed on two SCBA masks. The installation was easily performed. The system provided clear audio transmissions. Problems were encountered when the transceivers were configured in the VOX mode. The sounds of the SCBA air valving and noise patterns inside of the masks caused the transceivers to transmit inadvertently from these breathing sounds. No problems were experienced when the transceivers were used in the PTT mode. Vision through the maskpiece was not affected.

7. Boom microphone option: The microphone element was taped to the front of a mask equipped with a speaking diaphragm. Sound that was passed through the speaking diaphragm was picked up by the microphone. The mounting of the assembly was completed only with tape and therefore subject to misalignment. The audio transmitted by this configuration was clear, but at a lower volume than that of the other microphone options.

8. Throat microphone option: The throat microphones that were supplied by REMIC were found to be unacceptable. The band securing the microphone in position slipped easily when any stress was placed on the connecting cable. The positioning problem increased with skin perspiration. The alignment problems contributed to the audio transmission difficulties of garbled sound. Electrical modifications were performed to adjust the frequency response of the microphone system for increased intelligibility. The modifications improved the audio quality. The positioning problems could not be overcome so that sound quality was only fair even after modification - many sentences had to be repeated because the observers could not understand the transmissions.

   The throat microphone with modified velcro band positioning assembly was tested and found to provide acceptable communications quality voice reproduction. While not as "crisp" as the open air microphone options, no problems were encountered with readability of the transmitted signal. Tests by two users verified that the assembly was comfortable to wear and did not slip from position.

9. PTT switches: The shape of the press plate on the prototype PTT switch was such that the switches were easily actuated by pressure applied from contact with the protective clothing. The result was random transmissions caused by the personnel working at their assigned tasks. No problems were encountered

with the modified Motorola PTT switches in the same situations. The shape of the PTT button on the Motorola switches is such that it requires a definite motion for switch actuation. The switches were worn inside the suits and required careful positioning so that they could be actuated by pressing on the suit from the outside.

10. Battery packs: The transceivers operated with no battery failures during the testing procedures.

11. Repeater station: The repeater was tested in two modes, as a base station/command post and as a relay/repeater station. For command post use, the handheld microphone was used to direct those wearing the HCPE transceivers. The disadvantage of this mode is that those wearing the transceivers could hear only the command post - not others wearing transceivers. In the repeater mode, communications could be heard by all in the communications system. The repeater local microphone is operational in all modes and was used to direct operations. No problems were encountered with the repeater operation.

Suggestions for Improvement:

1. The HCPE transceiver control switches should be constructed in such a way that their position can be determined by touch, possibly by molding a raised edge around each switch button.

2. The LED indicators should be positioned so that the person in the suit can see them, possibly on a sloping panel near the top of the control unit. Also a TRANSMIT LED and a low battery LED should be added to aid in the check-out of the system.

3. The connectors for the MIC and PTT/CHARGER should be miniaturized and waterproofed.

4. The connecting cables should be flexible yet durable enough to take rough treatment.

5. The receiver volume should be increased.

6. A remote earphone jack should be provided for optional speakers or earphones.

7. The present transceiver speakers should be moved closer to the ears taking into account the position of the SCBA harness. This should increase the receiver volume.

8. The backstrap should be simplified. There are too many hooks, buckles, snaps and velcro strips. The loop provided for snapping to the SCBA ring should be lengthened.

9. The repeater channel (in the transceiver) should be replaced

with two other selectable channels for a total of three simplex channels (three channels transmit and receive).

10. Additional transceiver controls should be made available: microphone sensitivity, VOX threshold and VOX delay. The squelch can remain a screwdriver adjustment, but it should also be accessible.

11. Transceiver parts (transceiver and control cases) should separate from the vest for easy servicing.

12. The mask microphone parts must be cheap enough to permit them to be scrapped when the face shield becomes unusable or contaminated.

13. A microphone pick-up system should be developed that would snap into the front slots of the speaking diaphram allowing the system to be used without modifying the mask.

14. The repeater station should be redesigned so that it is in better shape factor for transportation. The self-contained approach should be retained so that the set-up time and operational simplicity are retained. A rapid charge battery system or replaceable battery system should be investigated.

VIII Considerations and Recommendations for System Production

1. HCPE Transceiver:

The transceiver should be produced as a commercial unit rather than a military spec device. The expense of qualifying all of the special component parts, assemblies and materials would yield a very expensive product - for no net operational gain. This product is one that could be considered expendable if it were to become contaminated to a high degree. In this case, the probability of routinely replacing expensive gear would decrease the appeal of the system to potential users operating with restricted budgets.

The transceiver must be tooled and produced using materials that are compatible with the rough environment in which the unit is to operate. The tooling will be expensive and critical, yet required if the end product is to pass environmental and functional drop tests. The internal construction should be made as modular as possible to facilitate repair at the local level.

Specific recommendations for the HCPE transceiver follow:

* The vest configuration should be retained and optimized to more closely integrate with the various levels of protective clothing and SCBA breathing apparatus. The transceiver should be constructed from materials that would allow the transceiver system to be worn on the outside of the Level B & C protective clothing. Receiver audio reproduction and volume can more easily be maximized if the transceiver is worn outside of these protective suits since the suit itself will not interfere with sound propagation. Wearing of the transceiver in this manner also solves the possible problems with sealing the antenna cable where it previously exited from under the protective suit.

* Further research should be performed to design an antenna system that can be integrated within the garment. An integrated system would eliminate the need for the antenna clamp assembly and external, removable antenna. The reliability of the system would be improved since a connecting cable assembly and several RF connectors would be eliminated. The usability of the product in relation to the various levels of protective clothing would also be improved.

* Modes of operation: The three modes of operation, VOX, PTT, and MONITOR should be retained. The VOX system should be improved, as suggested earlier, to tailor the VOX characteristics to the user's voice patterns.

* The number of channels should be expanded to three sets transmit and receive. Two of the sets could be dedicated to simplex communications while the third set configured to interface with a repeater system if desired.

* The receiver audio reproduction system should be redesigned to optimize the volume of sound reaching the ear. An audio output jack should be available for speaker or headphone options.

* Controls: User controls should be expanded to include those associated with VOX circuit adjustments. The controls should be oriented in a position so that the operator can easily access them through the wall of the protective clothing. Set-up controls, such as those associated with the VOX circuitry and microphone sensitivity, should be screwdriver adjustable and recessed so they are not accidentally disturbed. All controls should be waterproof.

* Indicators: The indicators should be oriented in a position so that the user of the transceiver can easily determine the operational status of his unit. A transmit indicator and a low battery warning indicator should be added to the dislay.

* Cables and connectors: All cables and connectors should be waterproof. The connectors should be locking to prevent accidental disconnection. Cable lengths should be optimized to increase user comfort.

* The battery pack should be removable as an assembly for field replacement. The battery should also have an intrinsic safety rating. A rapid charge system for battery pack recharging (in place of the overnight trickle charge system) should be designed. Battery capacity should be increased so that the transceiver operates for a longer time between recharges.

* Additional research is required in the field of microphone technology to optimize the microphone-VOX circuit so that it excludes noises from the SCBA systems. This next step in VOX technology will require the development of a "smart" VOX system that is programmed to respond to speech waveforms and reject all others. The development of this circuitry will require field trials and user interface to develop an acceptable system.

* Microphone systems: the microphone systems should be optimized for this class of service. The mask microphone system should be miniaturized. The production cost of the responder element in the mask microphone system should be low enough to consider it expendable if contaminated or damaged. A new throat microphone should

be designed using the light elastic and velcro closure system for securing to the throat in proper position. The microphone electronics should be optimized for the best frequency response and clearest speech reproduction on the neck. An additional microphone should be designed to snap in place on the speaking diaphragm on those SCBA masks so equipped. This microphone would eliminate any modifications to existing masks.

* Field testing of the unit indicated that the range was far in excess of that required. A power output level decrease to 0.5 watts seems advisable in light of the desire to extend battery life as much as possible.

2. Repeater Station

The repeater station should be considered for production even though the field testing data was inconclusive. The repeater is a valuable tool in establishing reliable communications where difficult terrain or structures cause problems with normal modes of operation. The repeater is also extremely useful in extending the range of communications in confined structures such as ships, culverts and tunnels.

3. General

* Test Standards. The HCPE communication system should be tested to the standards outlined in the RTI test plans (with exceptions noted).

* Certification. Each device should specifically receive:

  - FCC Part 15 receiver certification
  - FCC Part B1 and B3 type acceptance
  - Intrinsic safety ratings (based on Coast Guard requirements)

* Frequency allocation: The Coast Guard should petition the FCC for a set of frequencies assigned to this type of service. The "sharing" of frequencies is becoming less reliable as the number of users on any given service increases. It is within reason that a group of four channels in the marine band be assigned exclusively to emergency services, with limitations to use and power output. The creation of this service would guarantee that units arriving on the scene would all be able to communicate without interference from, and without interference to, other stations and services.

IX. Recommendations for Operating and Training Protocols.

Operating procedures and system use considerations for the Chemical Protective Clothing Communication System are discussed in the operation manuals for the engineering prototypes of the transceiver unit and the repeater, which are included as Appendix B and Appendix C to this report.

Recommendations for operating protocols:

1. The users of the HCPE system should standardize on no more than two of the microphone options. Optimization of the circuitry (for speech clarity) becomes progressively harder as the number of options increase. Compromises in the circuit designs should be kept to a minimum particularly in the HCPE communications system where reliability is critical.

2. All users of the HCPE system should be required to thoroughly understand the operation of VOX (voice operated transmitter) systems. Certain protocols in speech patterns are required to permit a VOX system to operate efficiently. A short training course should be developed for this purpose.

3. A simplified training course should also be developed to acquaint Coast Guard personnel with the basic operations of two-way radio equipment. Many misconceptions remain as to how and why radio transceivers function. The training would make personnel aware of the predictable communications problems which they are likely to encounter in the course of performing their tasks - and how to minimize these problems simply and effectively.

4. Further feedback on the final design of the HCPE system should be solicited from Coast Guard personnel prior to production tooling. As the ultimate users of this system in stressful situations, personnel should feel both comfortable and secure with the flexibility and the reliability of the iability of the communications hardware

Repair and Maintenance

Assuming that the HCPE system is production tooled, it is envisioned that the tooled, production transceiver and repeater will be of modular construction. The construction techniques will allow Coast Guard repair personnel to troubleshoot the units to a module level.

1. Malfunctions should be analyzed and repaired immediately. Any damage that could impair the environmental integrity of the unit should be referred to qualified personnel for the repair analysis.

2. All HCPE communications gear should undergo periodic preventive maintenance inspections for corrosion, broken or stressed connecting cables, defective or intermittent microphone components, inoperative controls, etc. These should be cleaned, adjusted and repaired as necessary.

3. Since the transceivers will be subject to rough treatment in their normal use, the transceivers should be checked once every six months for FCC compliance.

4. The transceivers should be disassembled to the major module level every six months and inspected internally for leaks and possible corrosion. Sealing gaskets should be replaced (not reused) to insure environmental integrity.

5. Repair of the connecting cables, microphones, and options should be performed at the local repair depot level. These defects are likely to be related to damage from use or wear. The replacement of the cable assemblies and repair of connectors can be accomplished with test equipment already available.

6. Repair of the control and transceiver circuitry modules will probably be most effectively performed at the factory service level. These modules contain components that may not be readily available in the field, or that require special handling techniques. Repairs could be performed on a rotating basis with the factory maintaining an inventory of tested, operational modules for quick return of service stock.

7. Local Coast Guard units should stock items that are easily replaced - spare batteries, extra microphones and spare cables. These items can be replaced at the unit level and the defective components forwarded to the appropriate repair agency for repair or replacement.

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TABLE OF CONTENTS

I. Introduction

This document represents the results of meetings with representatives of the U.S. Coast Guard and contacts with the U.S. Fire Administration to identify the requirements for the operational testing of the Firefighters or Ensemble Communication Transceiver. The major concerns of the firefighters and U.S. Coast Guard Strike Team members centered around the integrity and reliability of the firefighter/microphone interface. The technical characteristics of the radio itself were of less concern. The major concern about the radio hardware was that it be intrinsically safe in hazardous atmospheres. Another major concern voiced by Lt. Glenn of the Coast Guard Atlantic Strike Team was that the system not interfere with the fit or facial seal of self-contained breathing apparatus (SCBA).

The single greatest concern for operational testing purposes was the reliability and clarity of the line of communication between the firefighter and those on the fireground with whom he must maintain contact. All individuals interviewed cited several examples of the respective shortcomings of existing microphone subsystems. An overall preference for the currently available throat contact microphone was tempered by the need to use tape or VELCRO neck bands to keep the microphone positively secured against the throat. The Coast Guard Team members felt they would make the best judges of the operational effectiveness of the final radio design. The Team stated a desire to test any units developed in both training exercises and in real responses to hazardous material incidents. Coast Guard Strike Team members felt that a VOX-microphone built into the SCBA facemask would provide the best performance. Short of this, the Team members expressed a desire to see a better throat microphone that remained in place in spite of sweating and without the need for taping or strapping. One new voice-pickup product of

particular interest is the "Earmic" available from KAVCO Industries of California and TAD America in Hawaii. This device combines a bone conduction microphone and a speaker into a single ear-mounted unit. The TAD America device is certified as intrinsically safe and KAVCO Industries is contemplating development of a VOX version of their "Earmic." The KAVCO product is currently seeing successful use by the Huntington Beach, California Fire Department.

II. <u>Background</u>

A "breadboard" version of a portable fireground radio has been developed by REMIC Corporation to demonstrate the feasibility of producing a low-cost, reliable, ensemble communication system. The fireground radio was conceived R1 to provide the individual firefighter with automatic hands-free communications between himself and his associates and his captain. The hands-free operation of the radio is the major design requirement. Waterproof construction, light weight, ease of operation, and reliable maintenance of the line of communication are other design objectives for the unit. The fireman's need to have both hands free to carry out mission activities and provide for his personal safety is clear cut. Securing a high level of firefighter confidence in hands-free operation of the ensemble radio will require very high reliability in the voice-actuated microphone subsystem of the unit. Current portable R1 ensemble radio units employ throat contact microphones (see Figure 1), boom microphones, or bone conduction microphones when self-contained breathing apparatus (SCBA) are worn. Problems with these alternative microphone systems vary from the throat microphone slipping out of position to boom microphone activation by loud external sources of sound, and other unique problems with the conduction microphone. Improved design of the contact and conduction microphones or replacement is necessary if the operational effectiveness of

the Ensemble Communication System is to meet the stated requirements of the firefighting population for whom it is targeted. R1

Among the human factors constraints placed on the communication system's radio unit is its placement on the body of the wearer. The radio is to be located inside the outermost layer of protective clothing. This means inside the turnout coat of the firefighter and inside the outergarment (see Figures 1 and 2) of the U. S. Coast Guard's totally encapsulating Hazardous Chemical Protective Ensemble (HCPE). Any vests, harnesses, or supporting straps must compete for space with similar elements used for SCBA or found with inner garments. The radio unit itself may compete with air hoses or cooling garment components (e.g., the ice pouch) in the case of the Coast Guard's fully encapsulated suit (see Figures 2 and 3). Potential sites suggested by U.S. Coast Guard Atlantic Strike Team members in order of preference include high on the centerline of the chest in the area of the sternum, low on the front ribs, and on the side of the thigh. Crowding was given as the reason for not preferring a head mounted unit in the presence of SCBA and helmet straps.

III. Testing the Ensemble Radio Communication System R1

The testing of the Ensemble Communication System is divided into two parts. One test series is established to measure device performance under controlled laboratory conditions. The principal protocol for this test series is taken from an Electronic Industries Association Recommended Standard for portable/personal communication FM or PM equipment operating between 25-1000 MHz. Other subsystem specific tests will be proposed for different items that make up the ensemble radio. The second test series is based on the actual use of the radio units by firefighting/strike force teams initially engaged in training exercises and ultimately engaged in live responses to fireground or hazardous material incidents. The vehicles for conducting the R1

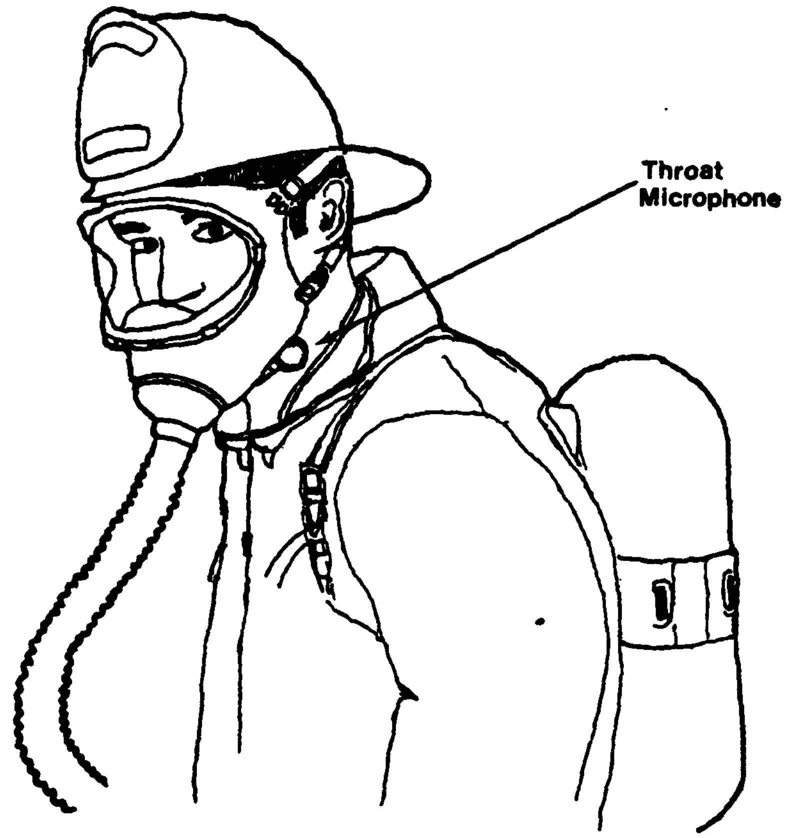

FIGURE 1 - THROAT MICROPHONE/SELF-CONTAINED BREATHING APPARATUS COMBINATION

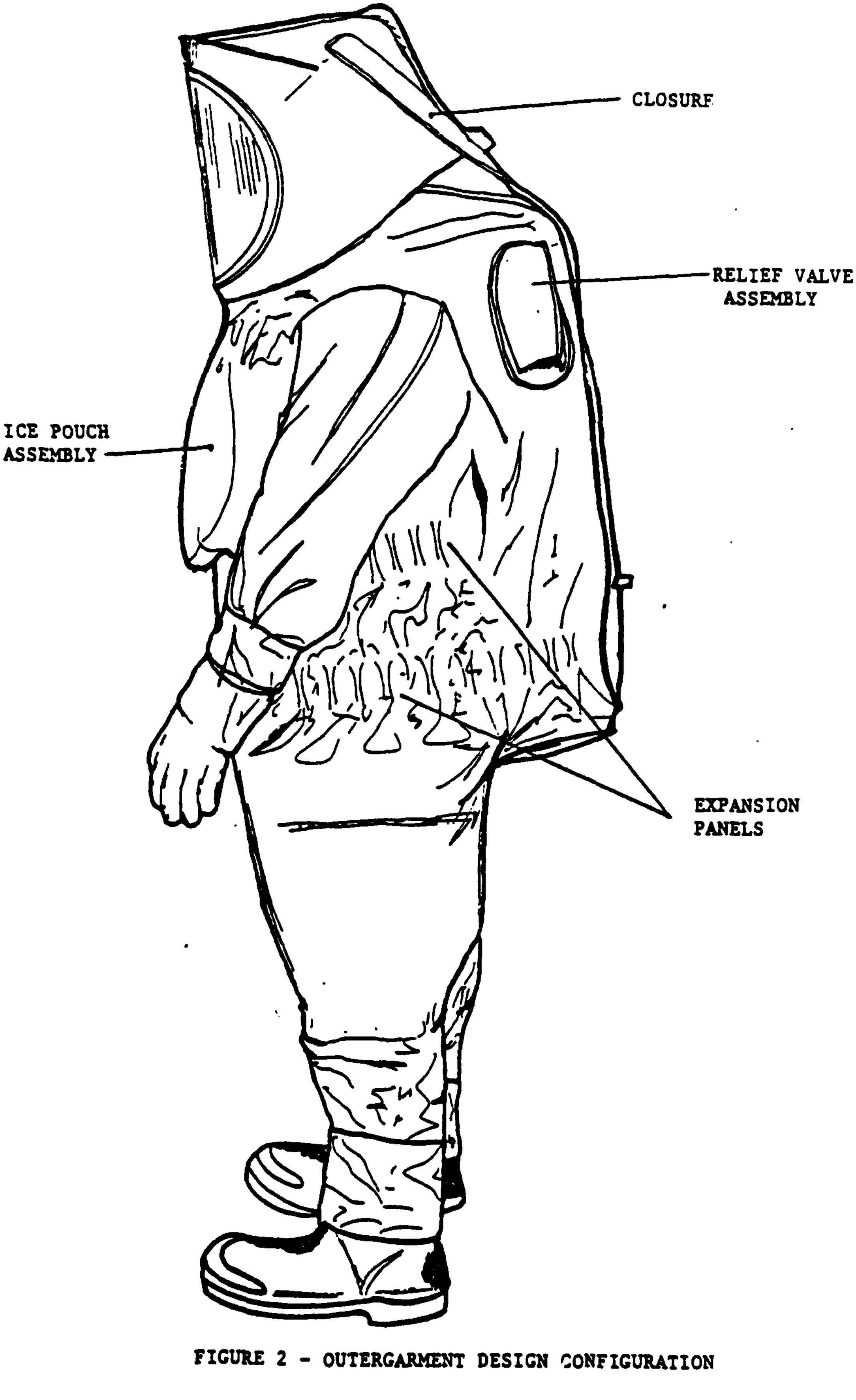

FIGURE 2 - OUTERGARMENT DESIGN CONFIGURATION

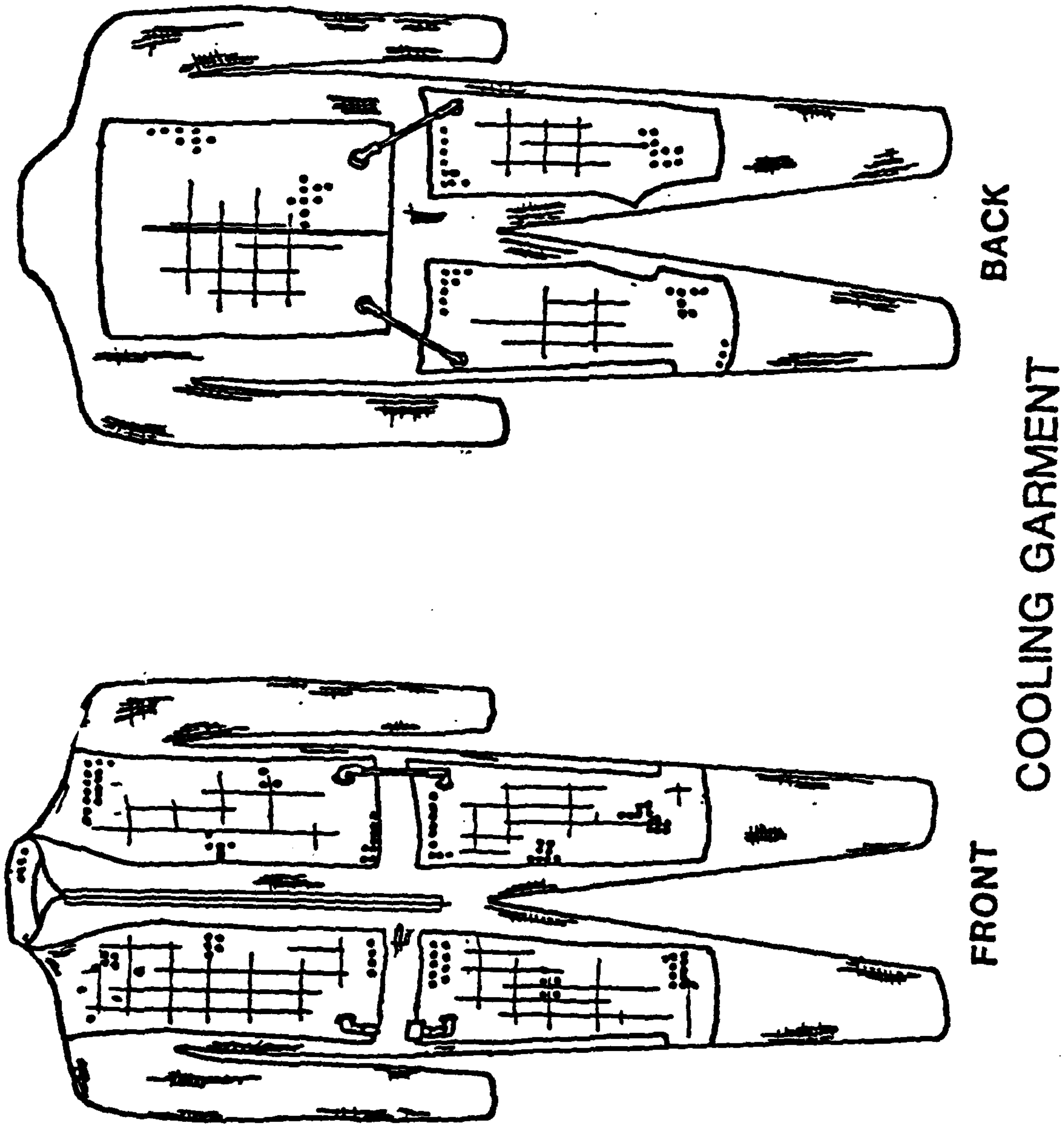

FIGURE 3 - COOLING GARMENT USED IN CONJUNCTION WITH TOTALLY ENCAPSULATED HCPE.

field-based tests are an annotated communication log and a survey questionnaire filled out by participating members of hazardous response or fireground test teams. The details of the field test communication log and survey questionnaire will be covered in a later section of this report. The following section represents a general approach for the controlled laboratory testing of the ensemble transceiver. R1 R1

IV. Controlled Laboratory Testing of the Device

For the purposes of the Ensemble Communication Transceiver Test Series, the scope and definition of the portable communications equipment is taken to be that of EIA Standard RS-316-B (Revision of RS-316-A) May 1979. R1

"1.1 Scope--This standard details the minimum performance requirements for portable/personal communicaton FM or PM equipments as defined in paragraph 1.2, except temperature operating range of the power source shall not be included. It excludes accessories like chargers, power boosters, batteries, etc.

1.2 Definition--Portable/personal communications equipment are radio transmitters, receivers, or combinatons of both, which can be hand-carried or worn on the person, and which are operated from their own portable power sources and antenna. Personal equipment is further defined as that which is capable of being worn directly on the person or within the clothing (e.g., surveillance or paging equipments) and is, therefore, subject to less severe environments than other classifications of portable equipment."

"Minimum Standards for Portable/Personal Radio Transmitters, Receivers, and Transmitter/Receiver Combination Land Mobile Communications FM or PM Equipment, 25-1000 MHz"

Also adopted for the controlled testing of the Ensemble Communication Transceiver hardware are the paragraphs and subparagraphs of EIA Standard RS-316-B. An outline of EIA Standard RS-316-B, Sections 2-5 is included in this report as Appendix A. R1

The prototype radio assemblies developed under this program should be tested using widely recognized standards for testing portable/personnel land mobile radios. Most of the technical performance characteristics of the radio will be tested in a laboratory setting in the first phase. These technical characteristics are more or less covered by various available standards. Some examples of standards or organizations whose standards have been used to evaluate portable UHF transceivers similar to the ensemble radio are presented in Table 1 below. R1

Table 1
Standards Which Have Been Used To Test Portable
UHF Transceivers and Transceiver Subsystems

TRANSCEIVER/SUBSYSTEM TEST FUNCTION	ORGANIZATION/STANDARD
1. Transmitter/Receiver Combination Performance	EIA Standard RS-316-B May 1979
2. Battery Pack/Internal Components intrinsic safety	a) Factory Mutual Research Corporation, "Intrinsically Safe Apparatus and Associated Apparatus for Class 1, Division 1, Hazardous Locations b) NFPA Standard 493
3. Radio/Battery Pack shock and vibration resistance	EIA Standard RS-316-B May 1979
4. Radio/Battery Pack weather proofing	MIL STD 810-C (Driven rain test)
5. Rechargeable Battery Pack performance	United Laboratories

The Ensemble Communication System and Subsystem tests identified by this minimum set of standards are to be superceded by more extreme fireground requirements where ever greater performance was called for in the list of desirable radio characteristics. Examples of more extreme requirements include: R1

1. Temperature extremes found inside the turnout coat or fully encapsulated suit vs standard temperature.
2. Full waterproof testing vs standard humidity.

The complete version of EIA Standard RS-316-B is incorporated by reference as part of the controlled laboratory testing of the Ensemble Communications System Device. The standard is available from the EIA at the following address: R1

Electronic Industries Association
Engineering Department
Standards Sales Office
2001 I Street, N.W.
Washington, D.C. 20006
Phone: (202) 457-4966

The test methods used to execute the test plan will be those explicitly identified in EIA Standard RS-316-B or the other recognized methods identified for the qualification testing of 450-512 MHz land mobile transmitter/receiver combinations. Alternative test methods can be used when it can be shown that excessive costs will be incurred in providing the test apparatus needed for the test method identified. If a test method can be developed and shown to be more suitable than the method specified in this test plan it may be substituted as an alternative test method upon the written approval of NASA.

To gauge the variability in the capacity of fabricated Ensemble Radios to meet or exceed stated performance specifications it is recommended than ten (10) units be put through the same battery of controlled laboratory tests. The standard deviations for the measured properties will provide useful information on the repeatability in device fabrication techniques. R1

V. Testing the Intrinsic Electrical Safety of the Device

A major test procedure to be applied to the Ensemble Communication System device is the test for the intrinsic safety of the device under National Fire Protection Association (NFPA) Standard 493. NFPA Standard 493 establishes the "Standard for Intrinsically Safe Apparatus and Associated Apparatus for use in Class I, II, and III, Division 1 Hazardous Locations." Classes I, II, and III represent degrees of hazard for locations under the National Electrical Code. Hazardous location Class I is the most dangerous. New Ensemble Communications System devices must be shown to provide at a minimum the same intrinsically safe quality of portable communication devices currently in use. Current U.S. Coast Guard portable/personal transmitter/ receiver combinations carry a label stating that the devices are "Intrinsically Safe for Class I, Division 1, Groups C & D." R1 R1

The U.S. Coast Guard need for intrinsic safety in their portable/personal transceivers follows from the dangers of explosive atmospheres often produced by hazardous materials incidents. Lower explosive limit (LEL) and permissible explosive limit (PEL) for various hazardous materials is used by the Coast Guard in determining a response to a hazardous material incident. Another Coast Guard measure of hazardous atmospheres is the determination of "Immediate Danger to Life and Health (IDLH)." In the presence of this type of atmosphere, self-contained breathing apparatus (SCBA) and fully encapsulated

suits are donned to protect the guardsman. Such situations require a continuous positive facepiece-to-face seal for the SCBA. Any microphone subsystem, whether contact or bone conduction, must never cause or contribute to a break in the facepiece-to-face seal or in a break in the closure of the fully encapsulated suit.

VI. Operational Testing Critical Issues

The Operational Testing of the Ensemble Radio Communication System will be divided into six broad types of critical test issues. Effective treatment of these issues will provide a thorough coverage of all areas of concern to the firefighter or the strike team member. The six types of critical issues include: R1

1. Mission performance
2. Human factors, safety, health
3. Survivability
4. Reliability, availability, maintainability
5. Training
6. Interoperability

Table 2 lists the six types of critical issues along with associated sets of performance attributes and the criteria for measuring the issues.

Table 2. Critical Operational Test Issues

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
I. Mission Performance	Communications Range	Shall operate satisfactorily up to 600 meters (1950 ft) under relatively unimpeded conditions and shall also be capable of reliable performance within a 10 story steel/concrete building structure.	Laboratory and field evaluation
	Three-mode operation - Voice-actuated (VOX) - Push-to-talk (PTT) - Receive only	Unit shall operate successfully in each mode with sidetone verification of user voice transmissions in PTT and VOX modes	Recorded observation on survey questionnaire by operating personnel
	Receiver sensitivity	< 1 microvolt at antenna terminal (~ 20 dB quieting)	Laboratory evaluation
	Communications channels	6 frequencies at the 450-470 MHz UHF band	Observation
	Transmission/reception clarity at frequencies within band	Received communications shall be loud and clear under relatively unimpeded conditions, and signal margin/antenna coverage shall be sufficient to provide 95% probability of intelligible reception of any 5 second voice message transmission	Recorded observations by fireground communications aide on communications log
	Communications coverage	Coverage shall be omni-directional for the entire frequency band of operation.	Laboratory evaluation

(Con't)

NOTE: Several early requirements for a Communications System targed for integration with the Firefighters' Integrated Response Equipment System (FIRES) have not appeared in the "breadboard" fireground radio assemblies and so have not been included as operational test items. These include: 1) a high/normal power mode switch, 2) an emergency warning tone, and 3) remote activate functions.

Table 2. Critical Operational Test Issues (Con't).

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
2. Human factors, safety, health	Radiation hazard to wearer	Radiated field intensity from the antenna shall meet personnel hazard requirements of USAS C95.1	Instrumented manikin
	Interference with physical motions	Shall not restrict outfitted firefighter's physical motions	Laboratory and field evaluation
	Physical interference with protective equipment	Shall not restrict closure of or bind articles of protective equipment	Laboratory and field evaluation
	Physical interference with breathing apparatus	Shall not impact the mask-to-face seal of breathing apparatus	Laboratory and field evaluation
	Acceptance	Fireground radio shall be acceptable and promote usage	Field evaluation and fireground personnel testimonials
	Size	Shall occupy minimum volume under turnout coat or fully encapsulated suit	Tape measurement
	Weight	Weigh less than 0.75 Kg (1.5 lbs.)	Weigh with balance
	Controls placement	Controls shall be placed so that they are operable by hand inside the protective outer garment.	Field evaluation
	Controls operability	Volume and push-to-talk operable with heavy gloves; no external connections shall be required to operate equipment	Field evaluation

(Con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
2. Human factors, safety, health (con't)			
	Don/Doff time	Don or doff time in seconds to be determined	Field evaluation
	Mobility	Fully suited subject shall be able to climb, reach, twist, crawl using both hands	Field evaluation
	Fit	Complete system and especially microphone and/or voice pickup technology must fit all sizes	Visual examination and tape measurement per ANSI Z89.3
	Bodily injury	External controls and protrusions shall be designed to preclude personnel injury.	Field evaluation

(Con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
3. Survivability	Exposure	Protection provided by outer garments	Field evaluation
	Durability	Years of service life to be determined	Field evaluation
	Waterproof	Survives immersion for 5 minutes in 82°C and 1°C water	Shower (driven rain, test), environmental chamber configured for moisture condensation on radio unit.
	Heat and smoke resistance	Equal to human levels	Unit mounted on instrumented manikin and exposed to heat and smoke generators in environmental chamber
	Shock and vibration	Survive 12 foot drop to concrete surface	Standard drop test
	Physical abuse resistance	Unit accepts normal fire ground impacts and handling	Field evaluation

(Con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
4. Reliability, availability, maintainability	Mean time between failures - Battery pack - Actuation elements Voice-actuation Push-to-talk Receive-only - Antenna - Wires - Connectors	Meet all performance requirements throughout service life	Field evalatuion equipment maintenance log
	Continuous operation from battery power supply	At least 2 hours from full charge assuming a 10% transmit 10% receive, 80% standby duty cycle	Laboratory and field evaluation
	Ancillary hardware replacement repair	Basic replacement repairs (e.g., battery, antenna, microphone) can be performed at ground base	Field evaluation
	Retention	Complete system and especially the microphone and/or voice pick up technology must remain in place throughout period of activity on fireground	Field evaluation and observation of non-retention by outfitted test subjects
	Line-of-communications	Loss of the line-of-communication with personnel on the fireground shall not be due to to a failure of the fireground radio equipment with particular emphasis on the voice-pickup technology subsystem, the battery subsystems, the radio controls subsystems, and the antenna subsystem.	Fireground command post communications log and post-incident observations recorded on survey questionnaire by fireground entry personnel

(con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
4. Reliability, availability maintainability (Con't)	Ease of maintenance	Positive seal on switches and controls	Standard testing methods for sealed switches

(Con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
5. Training	- Operator's manual	A radio operator's manual shall be prepared to accompany the fireground radio set	Observation
	- Training time	Training in the operation of the fireground radio shall be compatible with existing portable radio operation and require a minimum of training	Field evaluation

(Con't)

Table 2. Critical Operational Test Issues (Con't)

Critical Issues	Performance Attribute Descriptor	Criteria for Measuring the Issue	Test Method
6. Interoperability	. Noninterference with SCBA	Must not interfere or contribute to the breaking of the mask-to-face seal of SCBA	Laboratory and field evaluation
	. Noninterference with protective firefighting ensemble	Must not compromise the mobility or function provided by protective firefighting ensemble	Laboratory and field evaluation
	. Compatibility	Must be compatible with existing and near term planned systems and subsystems	Observation during field evaluation

VII. Field Tests of the Ensemble Communication System R1

The operational testing of the Ensemble Communication System in the field will entail the use of two test documents, an annotated communications log and the post-incident survey questionnaire. The communications log will be maintained by the communications aide(s) to the overall incident commander. The communications aide in conjunction with front-line personnel will coordinate for the pre-donning checkout of radio units during the breakout of equipment. The pre-donning checkout consists of a check test of all ensemble R1 radio controls, switches, indicators, and connectors. The radio elements to be tested include:

1. Antenna connection
2. Battery connection
3. Battery light
4. Busy lamp
5. Channel selection switch (6 settings)
6. Power/volume switch
7. Receiver squelch
8. Mode selection switch (3 settings)
9. Speakers
10. Microphone connection
11. Microphone(s)

Simple voice transmit and receive tests will be conducted between pairs of radio units as part of pre-donning checkout. Any malfunctioning radio will be replaced by a working unit and the identification and apparent source of the unit's malfunction will be recorded and later verified. A running log of modes of failure will be maintained through the operational field testing. The results of the malfunction log will be tabulated and used to identify areas of unacceptable subsystem performance.

The resources used to execute the operational field tests include the response team personnel, the protective ensemble (including hazardous chemical R1 encapsulated suits where called for), six to ten ensemble radio units,

self-contained breathing apparatus, and all appropriate supporting equipment (i.e. ladders, hoses, hand tools, fire suppression equipment, etc.). The response team is divided between the members of a command post and the fire-ground personnel.

The members of the command post includes the overall incident commander, sector officers, (responsible for specific areas of the fireground or specific fire ground functions) and aides. If small response teams are used for operational testing of the ensemble radio the overall incident commander (i.e. R1
fireground commander, site safety officer, local on-scene coordinator) will be directly in the communications test loop. This commander is supported by a communications aide who logs the voice transactions involved in the operational test. If a large response team and up to ten (10) radios are involved in the test the commander may delegate communications responsibilities wholly to sector officers. A large test team may require an additional assistant to share the work load of the communications aide. The minimum field test team should consist of six people, two (2) fireground entry people, two (2) backups for the entry pair, one commander or officer, and one communications aide. Each test team member is provided with a radio unit. In both training exercises and real incident scenarios different functional communications modes are allocated among the channels available. Standard communications procedures and scripts will be prepared for each functional communications mode, for example ladder company communications <u>vs</u> rescue company or hazardous materials team communications. Local department custom R1
will determine the specific format of messages and responses between front-line field personnel, between field personnel and command posts, and between field personnel and threat suppression apparatus personnel. Development of communications procedures will be the responsibility of the

communications officer who would also select the operators for each of the frequencies used in an exercise or incident. Among the procedures that must be established as part of the test exercise are:

1) Procedures for operation on the channels available,

2) Procedures for testing the communications readiness of the front-line personnel, R1

3) Procedures for logging the time and contents of communications,

4) Procedures for logging the status and location of committed personnel and equipment.

The operational field test protocol consists essentially of recording observations of the availability and clarity of communications over the course of an incident response. In both training exercises and real incident responses the necessary additional communications monitoring personnel must be provided by the fire department or Coast Guard strike team. The communications aide and any assistants will record a running log of fire ground communications using the format or a similar format to that in Figure 4. The first page of the field test communications log contains a header section for recording the identifying characteristics of a given test. This includes entries for the test number, test scenario and location, and the makeup of the communications test team. The rest of the body of the log form and subsequent pages of the log includes entries for the time and durations of communications, the channel used, the radio unit or team member called or calling, a message code number or summary, and indications of loud/weak and clear/distorted communications. While the communications environment for any given field exercise or live incident may produce conditions that outstrip the capabilities of the proposed ensemble communication system a general goal for R1 transmission/reception clarity as stated in Table 2 is a 95% probability

FIREGROUND RADIO FIELD TEST
COMMAND POST RADIO COMMUNICATIONS LOG

1. TEST NO. ______ 2. DATE ______ 3. RECORDER'S NAME ______ PAGE NO. ______
4. TEST SCENARIO & LOCATION ______

5a. COMMAND POST COMMUNICATIONS TEAM MAKEUP:

Role	Quan.	Name(s)	FG Radio Unit No.
Overall Incident Commander			
Communications Officer			
Communications Aide			
Communications Aide Assistant			

5b. FIRE GROUND COMMUNICATIONS TEAM MAKEUP:

Role	Quan.	Name(s)	FG Radio Unit No.
Deployed Firefighter Pair			
Backup Firefighter Pair			

6. DATE	7. LOCAL TIME SYMBOL ______ 8. TIME BEGUN	9. TIME ENDED	10. FREQUENCY (CHANNEL) USED	11. UNIT CALLED OR CALLING	12. MESSAGE NO. OR SUMMARY	13. COMM. LOUD/ WEAK	14. COMM. CLEAR/ DISTORTED
						L W	C D
						L W	C D
						L W	C D
						L W	C D
						L W	C D

NOTES:

FIGURE 4. INITIAL PAGE OF FIELD TEST COMMUNICATIONS LOG

of intelligible reception of any 5 second voice message transmission. This degree of satisfactory reception can be verified by tabulating the proportion of clear communications recorded in the Command Post Radio Communications Log. Communications which are too weak to be intelligible will be recorded as being distorted.

Calling and answering procedures will be established by the communications officer in preparation for a field test. Typical communications included in the field test would be test transmissions and radio checks. To establish a communications link the calling party might proceed as follows:

a. The caller listens to make sure that the calling frequency is not busy. When not busy, the caller turns on the transmitter and should say:

"(Unit or Firefighter Called), THIS IS
(Name or unit number of calling party),
OVER"

b. The reply to the initial call should be:

"(Name of calling party), THIS IS
(Name or unit number of answering party),
OVER"

If the calling frequency is different from the working frequency the initial calling party will request the called part to SHIFT to the working frequency. Once communication is reestablished on the working frequency the calling part can transmit a formal message.

c. The message transmission, which omits the name of the party called, should be:

"THIS IS, (Name or unit number of calling party),
(The message), OVER"

d. After receiving the transmission, the called party replies:

"THIS IS, (Name of party called),
(The response to the message),
OVER"

e. A further response is made if necessary, otherwise the transmission is concluded as follows:

"THIS IS, (Name or unit number of calling
party), OUT"

f. The called party will also conclude with:

"THIS IS, (Name or unit number of called
party), OUT."

If a test transmission is to be performed, the transmitting party first listens to make certain that the frequency on which the test is to be made is not busy. Usually permission is obtained prior to making a test.

g. Permission to make a test is obtained by saying:

"THIS IS, (Name or unit number of party testing),
TEST"

h. If the reply "WAIT" is not received from the answering party, the party testing may proceed with the test by saying:

> "THIS IS (Name or unit number of party testing), TESTING, (A number count or other phraseology which will not confuse listeners and of not more than 10 seconds duration), (Name or unit number of party testing), (Location and if appropriate, status, of the testing party at the time the test is made), OUT"

In addition to transmission field tests another major communications test performed frequently during field exercises and live incidents is the radio check. Requests for radio checks are made directly to each specific ensemble radio unit. The party requesting the radio check first establishes communications as indicated above. R1

i. After properly establishing contact, the calling party should say:

> "HOW DO YOU HEAR ME?"

j. The proper response to the radio check request is as follows:

> "I HEAR YOU LOUD AND CLEAR," or
> "I HEAR YOU WEAK BUT CLEAR," or
> "YOU ARE LOUD BUT DISTORTED," etc.

This procedure is repeated for all radio units operating under various conditions and at different locations on the fireground to determine the operational performance of the communications system in actual use. Simple radio check type messages like those indicated above can be used or more detailed observations of ensemble radio performance can be used for the message traffic between firefighters and the communications personnel in the R1

command post. In all field tests the major burden for observing and recording the presence and quality of clear lines of communciation will fall on command post personnel. Adequate numbers of recorders and procedures for allocating transmission and reception traffic among the recorders must be provided.

VIII. Post-Incident Survey Questionnaire

It is inevitable that some if not many of the field test events that represent failures of the ensemble radio system will not be captured and R1 recorded through messages to communications personnel at the command post. In order to obtain the additional observations of the personnel actively engaged in hazardous material or firefighting activities a post-incident survey questionnaire will be used. The questionnaire will contain items that correspond directly to the critical operational test issues included in Table 2 of this report. The questionnaire will be administered to all fireground personnel that were supplied with an ensemble radio for use in either a field R1 training exercise or a live incident. The questionnaire will at a minimum provide for the following types of questions:

Mission Performance

1) Did your radio transmit and receive satisfactorily up to the 600 meter range limit under relatively unimpeded conditions?
2) If operated in a steel/concrete building structure did your radio perform reliably at up to a 10-story separation between you and another radio unit?
3) What conditions did you find that seriously degraded the range of satisfactory communications?

4) Did your radio unit operate successfully in all three available modes: voice-actuated; push-to-talk; receive only?

5) Was your voice transmission verified in the PTT and VOX modes by a clear sidetone signal?

6) Did all six (6) channels available on your radio operate properly?

7) Were received communications loud and clear under relatively unimpeded conditions for the stated range of the radio unit?

8) In your estimate what was the percentage of intelligible receptions out of all receptions received by you?

9) In general, did the radio unit perform up to the level that you expected from what you were told? If it did not, why not?

10) What are your dissatisfactions with the radio, if any, in terms of mission performance?

<u>Human Factors, Safety, Health</u>

11) Did the method for wearing the various elements of the radio restrict your physical motions?

12) Did the method for wearing the radio interfere with other necessary protective garments or equipment?

13) Did the method for wearing the radio interfere with the mask-to-face seal of breathing apparatus?

14) Are the controls of the radio placed so that you can operate them by hand inside your protective outer garment?

15) Are the volume and push-to-talk controls operable with heavy gloves?

16) Are don and doff times for the radio system sufficiently short?

17) When fully outfitted and wearing the radio were you able to climb, reach, twist and crawl using both hands?

18) Did you ever find that you were at risk of personal injury due to the protrusion of the external controls or other external parts of the radio?

19) What are your dissatisfactions with the radio, if any, in terms of human factors, safety, and health?

Survivability

20) Did the manner in which the radio is worn ever expose the unit directly to destructive fireground elements?

21) Have you developed any impressions of the durability of the ensemble radio? If so what are they? R1

22) Have you found that the radio unit accepts normal fireground impacts and handling while continuing to operate normally?

23) What are your dissatisfactions with the radio, if any, in terms of survivability?

Reliability, Availability, Maintainability

24) What has been your experience as to the reliability of major radio parts such as:

a) the battery pack

b) the controls and activation elements

c) the antennas

d) wires

e) connectors?

25) Did you find that the battery power supply gave you at least 2 hours continuous operation from full charge?

26) Did the complete radio system and especially the microphone and/or voice pick up elements of the radio remain in place providing a positive line of communications throughout your period of activity on the fireground? If not explain the causes of the problem in detail?

27) Did a failure in any of the following radio subsystems cause a loss of a line of communication during your period of activity on the fireground:

a) voice pickup

b) battery

c) radio controls

d) antenna?

28) What are your dissatisfactions with the radio, if, any in terms of reliability, availability, and maintainability?

Training

29) Is the operator's manual clearly written and easy to understand?

30) Is the operation of the ensemble radio compatible with existing portable radio operating procedures? R1

Interoperability

31) Did you find that the ensemble radio could be operated satisfactorily in conjunction with the rest of the protective ensemble? R1

32) In your opinion is the ensemble radio compatible with existing and near-term planned firefighting/hazardous material systems and subsystems? If not please explain.

33) What are your dissatisfactions with the radio, if any, in terms of interoperability?

IX. Conclusions and Recommendations for Field Test Implementation

Interviews with firefighting professionals and members of the Atlantic Strike Team of the U. S. Coast Guard National Strike Force have identified the key issues of concern for the operational field testing of the Ensemble Communication Transceiver. The key test issues in order of priority are: R1

1) The verification of the intrinsic safety of the radio

2) The non-interference of the radio with facemasks and breathing apparatus

3) Very high availability of a clear line of communications to other radio units (this is considered to be primarily a function of the reliability of the voice/microphone interface)

4) Reliable hands free operation

5) Human factors performance of the radio in terms of ease of operation, security of control settings from accidental switching, compact size, light weight, etc.

6) Technical performance of the radio in terms of range, noise suppression, power levels, etc.

The intrinsic safety and technical performance of the radio are best tested using appropriate published standards under controlled laboratory conditions. The radio features that impact the response team member's confidence in having a reliable line of communications during his time on the front line are best tested during training exercises and ultimately during live incidents. Two R1 recording documents have been identified as providing the necessary vehicles for documenting the field performance of the ensemble communication transceiver. The first is a communications log for recording all communications that occur during a field test with provisions for recording observations on the reliability and quality of the lines of communication. The second recording document is a post-incident survey questionnaire which is completed by all response personnel assigned an ensemble radio in the course of a field test. The results of the questionnaire are evaluated to identify R1 elements of the Ensemble Communication Transceiver which will require further improvements.

Comments made by many of the individuals contacted indicated there is great interest among fire departments and the Coast Guard Strike Teams in field testing an improved ensemble radio. There should be no problem in finding groups to participate in the implementation of the Ensemble R1 Communication Transceiver field test.

APPENDIX A

Outline of EIA Standard RS-316-B May 1979

Sections 2 through 5

Minimum Standards for Portable/Personal Radio Transmitters, Receivers, and Transmitter/Receiver Combination Land Mobile Communications FM or PM Equipment, 25-1000 MHz

APPENDIX B

Excerpt from Factory Mutual Reseach Intrinsic Safety Standard

Approval Standard - Intrinsically Safety Apparatus
and Associated Apparatus for Use in Class I, II and III
Divison 1, Hazardous Locations

APPROVAL STANDARD

INTRINSICALLY SAFE APPARATUS

AND

ASSOCIATED APPARATUS

FOR

USE IN CLASS I, II AND III

DIVISION 1, HAZARDOUS LOCATIONS

CLASS NUMBER 3610

OCTOBER 1979

Factory Mutual System

Factory Mutual Research

1151 Boston-Providence Turnpike
Norwood Massachusetts 02062

HOW TO APPLY FOR INTRINSIC SAFE EXAMINATIONS

Send a letter requesting an examination addressed to:

Instrumentation Section Manager
Factory Mutual Research Corporation
1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062

The letter should indicate the Class(s), Division(s) and Group(s) for the hazardous locations you wish the examination to cover.

One copy of the following documentation should be submitted, logically organized and neatly assembled into an indexed bound package.

(a) A complete list of all models and options by Class, Division and Group.
(b) A list of major or specific use application of the equipment.
(c) A system block diagram showing the location (i.e., hazardous or non-hazardous location) and inter-connection of equipment.
(d) Installation, operation, and maintenance instructions.
(e) Circuit physical layout drawing(s), schematic(s), and parts list(s).
(f) Assembly drawings showing overall physical separation of safe and unsafe circuits if not shown in circuit layout drawing.
(g) Drawings, specifications, and source control information for all protective components.
(h) Quality control documentation, and test procedures for all protective components and assemblies.
(i) Drawing(s) showing proposed labels to be applied to final product(s).
(j) If available, test report(s) by internationally recognized testing laboratories (e.g., CSA, PTB, BASEEFA).

TABLE OF CONTENTS

Factory Mutual Research

1151 Boston-Providence Turnpike
Norwood, Massachusetts 02062

Class No. 3610
October 1979

APPROVAL STANDARD

INTRINSICALLY SAFE APPARATUS

AND

ASSOCIATED APPARATUS

FOR

USE IN CLASS I, II AND III

DIVISION 1, HAZARDOUS LOCATIONS

NOTICE: The asterisk following the subsection number signifies that explanatory material on that paragraph appears in Appendix A.

I INTRODUCTION

1.1 This standard serves as the basis for Factory Mutual approval of intrinsically safe apparatus and associated apparatus. This standard provides requirements for the construction and testing of electrical apparatus, or parts of such apparatus, whose circuits are incapable of causing ignition in Division 1 hazardous locations as defined in Article 500 of the National Electrical Code, NFPA-70.

1.2 Intrinsically safe apparatus and associated apparatus (including wiring) is apparatus in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under the test conditions prescribed in this standard, of causing ignition of a specified mixture of flammable or combustible material in air.

1.3 Factory Mutual approval is based on satisfactory evaluation of the product and manufacturer in the following major areas:

1.3.1 Examination and tests to evaluate: (1) the suitability of the product; (2) the operation and performance of the product as required by Factory Mutual and, as far as practical; (3) the durability and reliability of the product.

1.3.2 Periodic examination of the manufacturing facilities to evaluate: (1) the manufacturer's ability to produce the product as examined and approved; (2) the quality control procedures applied to the product; and (3) the marking procedures which shall be used to identify the product.

1.4 Continued approval is based upon: (1) production or availability of the product as currently approved; (2) the continued use of acceptable quality control procedures; and (3) satisfactory field experience.

1.5 The requirements of this standard identify Factory Mutual approval tests and practices. Devices which do not conform to these requirements may be approved if they meet the intent of this standard. Conversely, those that do conform may not be approved if other conditions prevail.

1.6 The construction, tests and marking required by this standard correspond, in general, to the National Fire Protection Association standard for Intrinsically Safe Apparatus and Associated Apparatus For Use In Class I, II and III, Division 1 Hazardous Locations, NFPA - 493 (1978)[1]. NFPA-493 was the result of extensive committee activity and analysis, coupled closely with previous work done by the Instrument Society of America and the International Electrotechnical Commission.

[1]Available from National Fire Protection Association, 470 Atlantic Ave., Boston, MA 02210

II SCOPE

2.1* APPLICATION

This standard shall apply to:

(1) Apparatus or parts of apparatus in Class I, II or III, Division 1 locations as defined by the National Electrical Code, NFPA-70.

Note: Section 500-2(a) of NFPA 70-1978, National Electrical Code, states that equipment approved for Division 1 locations shall be permitted in Division 2 locations of the same class and group.

(2) Associated apparatus located outside of the Class I, II or III, Division 1 location whose design and construction may influence the intrinsic safety of an electrical circuit within the Class I, II or III, Division 1 location.

2.2* REQUIREMENTS

These requirements are based on consideration of ignition in locations made hazardous by the presence of flammable or combustible material under normal atmospheric conditions.

2.2.1 For the purposes of this standard, normal atmospheric conditions are considered to be:

(1) An ambient temperature of 40°C (104°F);
(2) An oxygen concentration not greater than 21 percent; and
(3) A pressure of one atmosphere.

2.3 MECHANISMS OF IGNITION

2.3.1 This standard does not cover mechanisms of ignition from external sources such as static electricity or lightning, which are not related to the electrical characteristics of the apparatus. However, the possibility of static charge on polymeric materials and ungrounded metal parts shall be considered during the approval examination.

2.3.2 This standard does not cover apparatus based on high voltage electrostatic principles (i.e., electrostatic paint spraying).

2.4 APPLICABILITY OF OTHER STANDARDS

2.4.1 Except where modified by the requirements of this standard, intrinsically safe and associated apparatus shall comply with the applicable requirements for ordinary locations, in accordance with FM Approval Standard 3820.[1]

[1]As another example of requirements for ordinary locations, see ANSI C39.5 Safety Requirements for Electrical And Electronic Measuring and Controlling Instrumentation, available from the American National Standards Institute, 1430 Broadway, New York, NY 10018

Exception: Circuits operating below extra-low voltage or limited-power are not included in the scope of FM Approval Standard 3820. Extra-low and limited-power circuits are defined as:

Extra-Low Voltage Circuit

An extra-low voltage circuit is one in which the maximum voltage measured between the conductor or part in question and its associated circuit common is not more than 30 V rms (sine wave) or 60 V dc.

Limited-Power Circuit

A limited-power circuit is one in which the maximum power available from the circuit does not exceed 150 watts as measured by a watt meter and an external test resistor connected in parallel to the circuit load after one minute.

2.4.1.1 Intrinsically Safe Apparatus or Associated Apparatus which have one or more circuits operating above and below the specified levels for extra-low voltage or limited power circuits are subject to the requirements of FM Standard 3820 from two aspects. In these cases, the requirements are applicable only to the circuits or parts of a circuit that exceed the specified levels and between those that do and those that do not exceed the specified levels This is to assure that the required degree of protection against electrical shock and fire is provided where necessary and that the inherent protection afforded by the below limit circuits is not compromised. This concept also applies to equipment or accessories rated for connection to other circuits for measuring purposes, etc. and exceeding the specified levels for extra-low voltage and limited power circuits.

2.4.1.2 Whether circuits are extra-low voltage or power limited is determined by measurement.

2.4.2 Associated apparatus and circuits shall conform to the requirements of the location in which they are installed[1].

[1]For guidance on installa ion, see ANSI/ISA RP12.6, Installation of Intrinsically Safe Instrument Systems in Class I Hazardous Locations, available from the Instrument Society of America, 400 Stanwix St., Pittsburgh, PA 15222.

III DEFINITIONS

3.1 ASSOCIATED APPARATUS

Apparatus in which the circuits are not necessarily intrinsically safe, but which affect the energy in the intrinsically safe circuits and are relied upon to maintain intrinsic safety.

3.2 CLEARANCE DISTANCE

The shortest distance measured in air between conductive parts.

3.3 CREEPAGE DISTANCE

The shortest distance measured over the surface of insulation between conductive parts. Air gaps less than 0.04 in. (1 mm) are not considered to interrupt the surface.

3.4 FAULT

A defect or electrical breakdown of any component, spacing, or insulation which alone or in combination with other faults may adversely affect the electrical or thermal characteristics of the intrinsically safe circuit. If a defect or breakdown leads to defects or breakdowns in other components, the primary and subsequent defects and breakdowns are considered to be a single fault.

3.5 FUSE PROTECTED SHUNT DIODE BARRIER ASSEMBLY

See definition under protective component or assembly.

3.6 FUSIBLE-RESISTOR PROTECTED SHUNT DIODE BARRIER

See definition under protective component or assembly.

3.7 INTERNAL WIRING

Wiring and electrical connections that are made within the apparatus by the manufacturer. Within racks or panels, interconnections between separate pieces of apparatus made in accordance with detailed instructions from the apparatus' manufacturer are considered to be internal wiring.

3.8 INTRINSICALLY SAFE APPARATUS

Apparatus in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under the test conditions prescribed in this standard, of causing ignition of a specified mixture of flammable or combustible material in air. This apparatus is suitable for use in Division 1 locations.

3.9 INTRINSICALLY SAFE CIRCUIT

A circuit in which any spark or thermal effect, produced either normally or in specified fault conditions, is incapable, under the test conditions prescribed in this standard, of causing ignition of a specified mixture of flammable or combustible material in air.

3.10 NORMAL OPERATION

Intrinsically safe apparatus or associated apparatus conforming electrically and mechanically with its design specification.

3.11 PROTECTIVE COMPONENT OR ASSEMBLY

A component or assembly which is so unlikely to become defective in a manner that will lower the intrinsic safety of the circuit it may be considered not subject to fault when analysis or tests for intrinsic safety are made.

3.11.1 Shunt Diode Barrier Assembly

A fuse or resistor protected diode barrier.

3.11.2 Fuse Protected Shunt Diode Barrier Assembly

A network consisting of a fuse, voltage limiting shunt diodes and a current limiting resistor designed to limit current and voltage. The fuse protects the diodes from open circuiting when high fault current flows.

3.11.3 Resistor Protected Shunt Diode Barrier Assembly

A network that is similar to a fuse protected shunt diode barrier with the exception that the fuse is replaced by a resistor.

3.11.4 Fusible-Resistor Protected Shunt Diode Barrier Assembly

A network that is similar to a fuse protected shunt diode barrier with the exception that the fuse is replaced by a fusible-resistor.

3.12 RESISTOR PROTECTED SHUNT DIODE BARRIER ASSEMBLY

See definition under protective component or assembly.

3.13 SHUNT DIODE BARRIER ASSEMBLY

See definition under protective component or assembly.

3.14 SUPPLY VOLTAGE

The nominal operating voltage applied by an external source to the apparatus or associated apparatus.

IV EVALUATION OF INTRINSIC SAFETY

4.1 FUNDAMENTAL REQUIREMENTS

4.1.1* Intrinsically safe apparatus, associated apparatus and circuits shall meet the two basic requirements specified in 4.1.2 and 4.2. Intrinsically safe apparatus with frequently operating contacts in parts of the apparatus likely to be exposed continuously or for long periods to a flammable atmosphere should have such contacts provided with supplementary protective measures.

Examples of supplementary protective measures:

(a) Hermetically sealed enclosures of quality obtained by fusing glass;
(b) Protection by an explosion-proof enclosure;
(c) Doubling of the factors applied on energy.

4.1.2 The energy available in the hazardous location shall not be capable of igniting the hazardous atmospheric mixture specified in Appendix C2 due to arcing or temperature during normal operation or under fault conditions.

4.2 NORMAL OPERATION

4.2.1 Normal operation shall include all of the following:

(a) Supply voltage at maximum value. This maximum voltage to be applied for normal operation tests shall be 1.1 times the manufacturer's specified nominal voltage for which the equipment has been designed.

Note: Due to international interests of manufacturers and at their specific request Factory Mutual will examine equipment at 1.15 times the manufacturer's specified nominal voltage.

(b) Environmental conditions within the ratings given for the apparatus or associated apparatus;
(c) Tolerances of all components in the combination that represents the most unfavorable condition;
(d) Adjustments at the most unfavorable settings;
(e) Opening, shorting, and grounding of the field wiring of the intrinsically safe circuit being evaluated.

Note: Opening means a complete separation of all strands of the wiring.

4.2.2* Normal operation shall include an additional factor for test purposes of 1.5 on energy. Such factors shall be achieved according to the procedures outlined in Section 13.2. Before faults are introduced the apparatus shall be in normal operation as specified in Section 4.2.

AD-A170 863 DEVELOPMENT OF A COMMUNICATION SYSTEM COMPATIBLE WITH CHEMICAL PROTECTIVE CLOTHING AND EQUIPMENT(U) REMIC CORP ELKHART IN B D BLOOD ET AL. 23 JUN 86 2/2

UNCLASSIFIED USCG-D-18-86 NAS8-36456 F/G 6/17 NL

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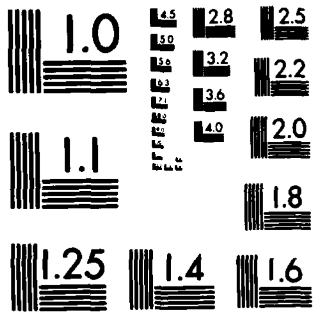


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Note: Factors given in this standard differ from those published in the Canadian and CENELEC standards. This standard bases the 1.5 factor on energy while other standards base the 1.5 factor on current or voltage, which may result in a 2.25 factor on energy. Due to international interests of manufacturers and at their specific request Factory Mutual will examine equipment using the 1.5 factor on current or voltage.

4.3 FAULT CONDITIONS

4.3.1 Fault conditions shall include the following:

(a) The most unfavorable single fault and any subsequent related faults, with an additional factor of 1.5 applied to energy;
(b) The most unfavorable combination of two faults and any subsequently related faults, with no additional factor.

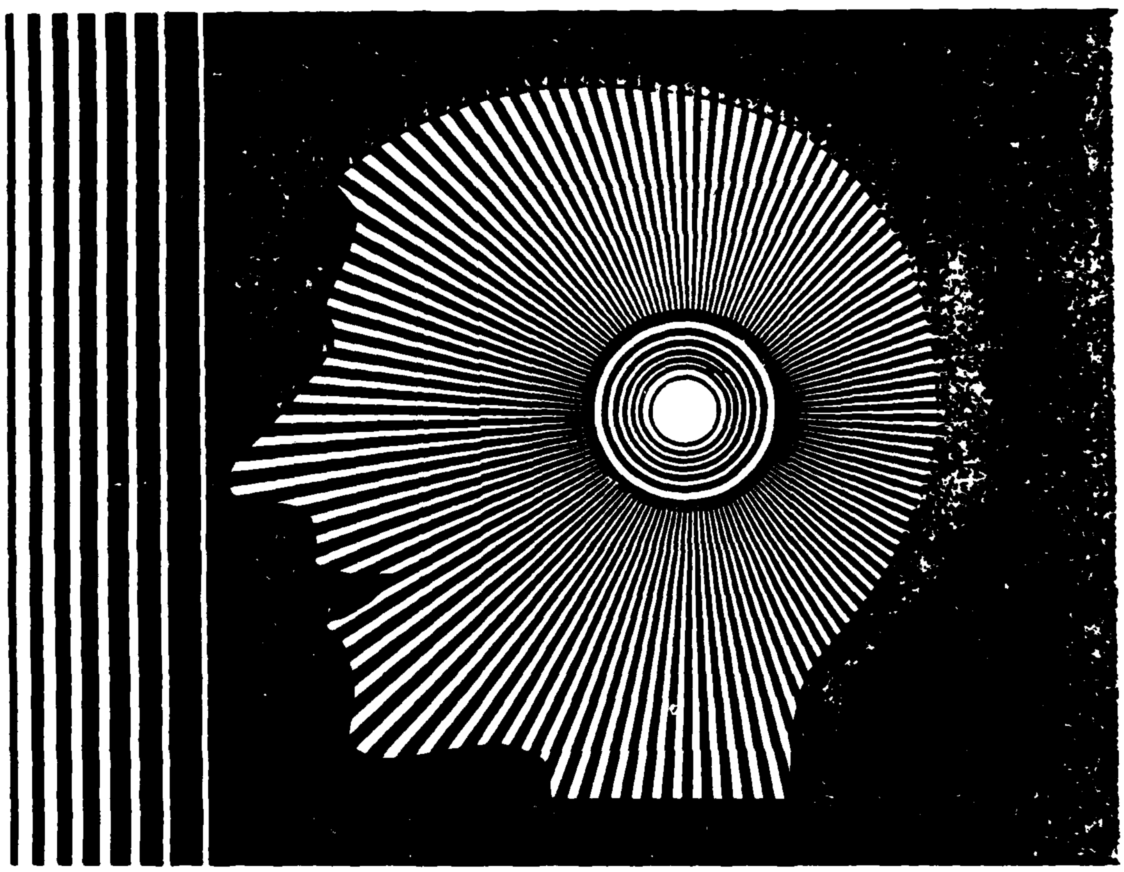
Such factors shall be achieved according to the procedures outlined in Section 13.2.

APPENDIX C

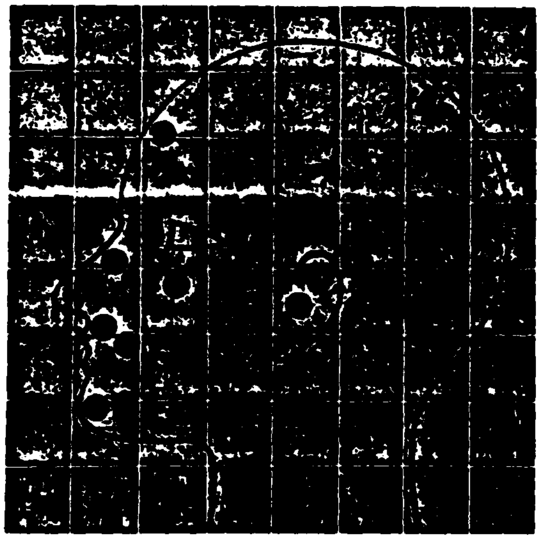
Currently Available Ear Microphone Products

TAD EARMIC
EAR MICROPHONE SYSTEM

JUST WHISPER TO SPEAK WITH HIM MILES AWAY TAD EAR-MIC IS A UNIQUE 2 WAY COMMUNICATION DEVICE TO TALK AND LISTEN THROUGH YOUR EAR. IT PERMITS HAND-FREE OPERATION IN HIGH NOISE ENVIRONMENTS
COUPLED WITH TOUGH-LINE TAD RADIOS, THE EAR-MIC ALLOWS YOU TO OPERATE YOUR FIELD COMMUNICATIONS UNDER SEVERE ENVIRONMENTAL CONDITIONS, INCLUDING EXTREME HIGH NOISE LEVELS, ABNORMAL TEMPERATURES VIBRATION AND SHOCK.

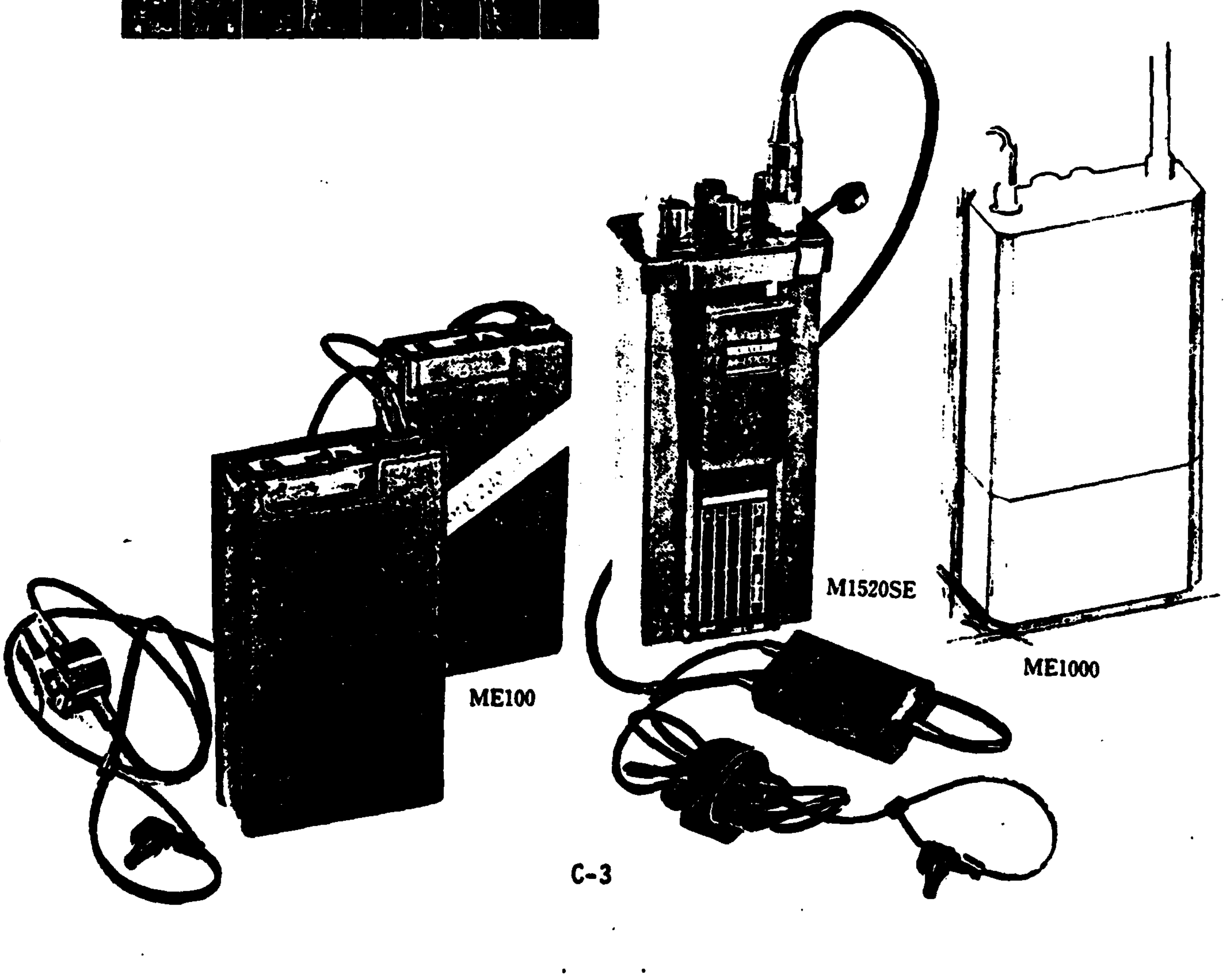


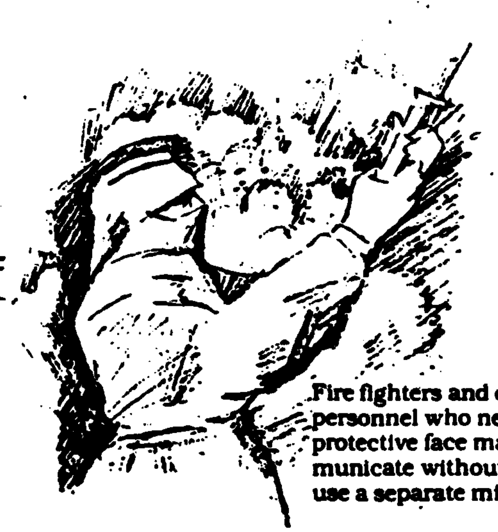
CHOICE OF THE PROFESSIONALS



THE TAD EAR-MIC HAS BEEN SPECIALLY DESIGNED TO PROVIDE CLEAR SPEECH COMMUNICATIONS BY MEANS OF BONE-CONDUCTION. OUR BONE CONSTRUCTION OF THE HUMAN HEAD IS SUCH THAT VIBRATIONS OCCUR WHEN WE SPEAK THROUGH VARIOUS RESONANT POINTS

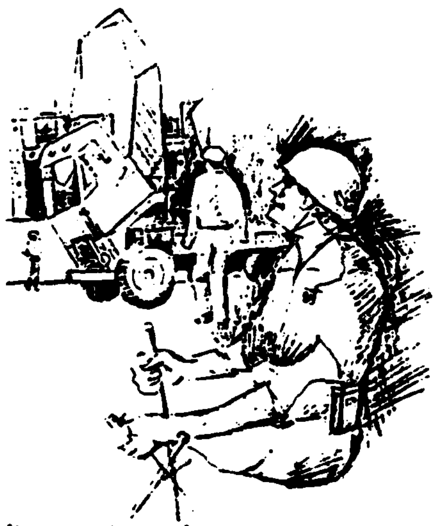
FOR CONVENIENCE, IT IS POSSIBLE TO USE A SINGLE TRANSDUCER FITTED IN THE EAR TO PROVIDE BY TRANSMISSION AND RECEPTION OF SPEECH MESSAGES.





Fire fighters and other rescure personnel who need to wear protective face masks can communicate without the need to use a separate microphone.

Police forces and security services often require to use 2 way radio communications unobtrusively in crowded areas.



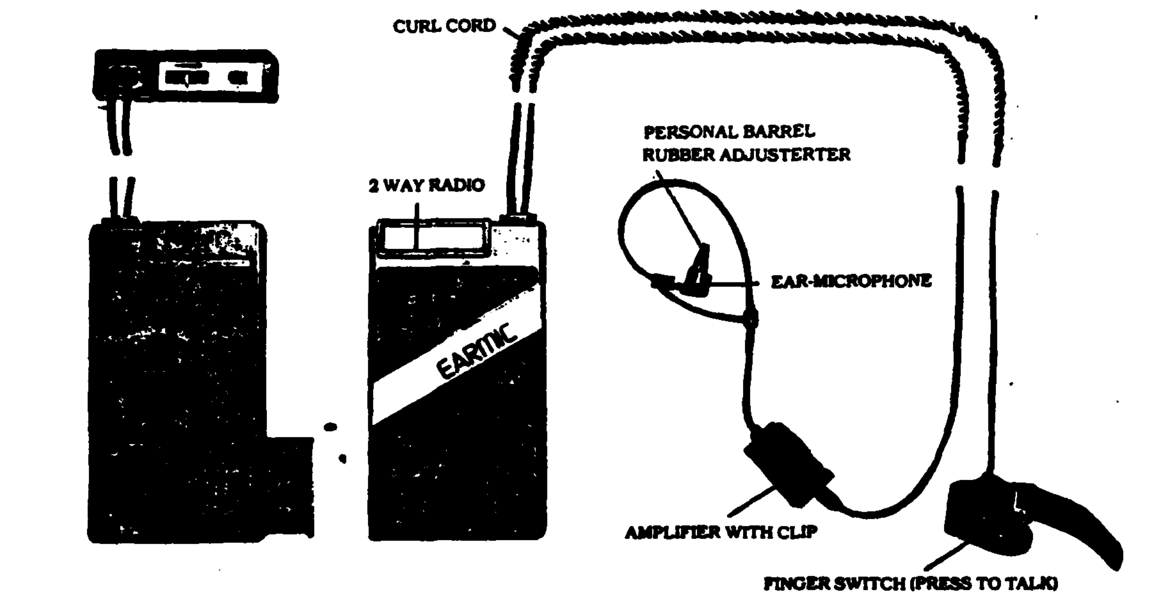
In military training, the TAD ear-mic allows personnel to communicate in a whisper with hands-free operation.

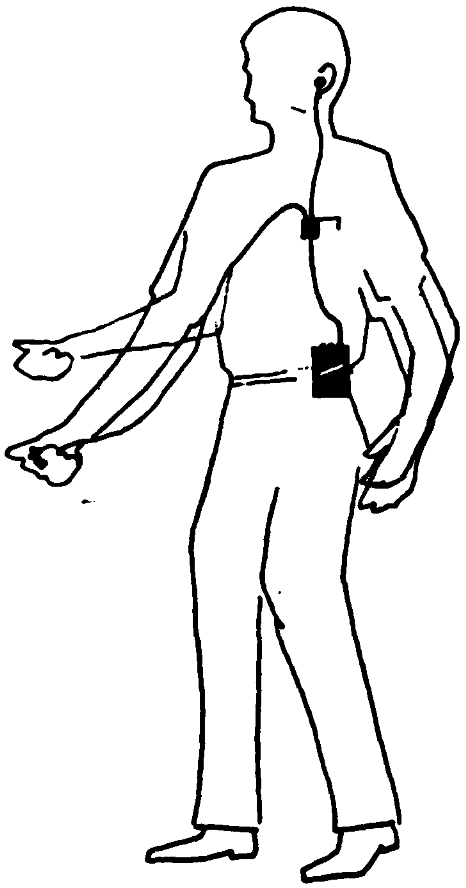
Radio operation within construction sites can be performed easily and efficiently even in high noise areas.

Operators of noisy machinery in factories have no difficulty in conversing with each other by using ear-mic.

Forestry and mining industry find the ear-mic beneficial in overcomming dangerous situations which can cause serious injuries due to the inability to communicate in noisy environments.

DESCRIPTIONS OF PARTS

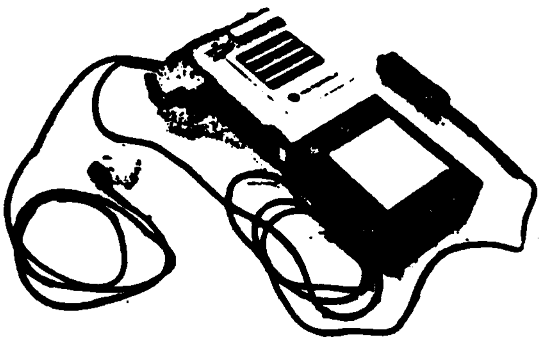




SPECIFICATIONS		FCC/DOC Pending	FCC/DOC Type Accepted
	Pocket Size Medium Duty	Pocket Size Heavy Duty Water Resistant Crush Proof	Extra Heavy Duty Water Proof Intrinsically Safe Crush Proof
Model	ME100	ME1000	M1520SE
Frequency Range	150MHz	VHF/UHF	VHF/UHF
RF Output	100mW	up to 3W	up to 5W
Number of Channel	1	up to 4	up to 6
Power Supply	2.4VDC	7.2/9.6VDC Rechargeable Nicad Battery Pack	12.0VDC
Operation		Press to talk. Simplex or Semi Duplex	
Ambient Temperature	-10 ~ +50	-30 ~ +60	-30 ~ +60
Ambient Noise Level		Satisfactory communication under 100 Horn (130 Horn with Ear Cover Pad)	
Dimentions (W × D × H)	75 × 23 × 135mm (3 × 7/8 × 5-1/2in.)	70 × 37 × 125mm (3-3/4 × 1-1/2 × 5in.)	72 × 52 × 164mm (2-7/8 × 2 × 6-1/4in)
Weight	280g (10oz)	400g (15oz)	780 (29oz)

NEW — PRODUCT — RELEASE

KAV-COM - A new technology concept that permits you to transmit and receive through your ear.



KAV-COM permits clear voice transmission to be sent and received through the earpiece. The transducer mounted in the ear picks up sound energy through the otolarynx canal as the user is talking. These sounds are fed into an interface amplifier module which is an integral part of the KAV-COM unit. They are then transmitted through the users radio.

Custom molded to the individual users own ear, the earpiece snaps on or off of the KAV—COM transducer module. This allows anyone with their own earpiece extensive flexibility and mobility when using the dynamic new KAV-COM.

The system can be installed in virtually any VHF, UHF, or HF radio and when disconnected from the radio, returns to it's former normal operating mode and capability.

KAV-COM'S ear to radio interface picks up minute sound energies from the otolarynx canal as the person talks. These are amplified through a control module and transmitted through the user's radio.

KAVCO Industries Inc.

Sales Office: 416 East Alondra Blvd. • Gardena, CA 90248 • (818) 782-2902
Corporate Office: (213) 324-2401

KAV-COM

HISTORY

While the concept of throat and ear type microphones is not new, the constant problem associated with each, that of interference from outside *ambient* noises with the basic voice range frequencies was totally unacceptable and thus the concept was virtually discarded.

The concept of a molded earpiece to reduce ambient noise has been used successfully and was accepted as commonplace as well.

However, the idea of plugging up the outside ear in combination with providing a miniature implanted *transducer* unit, capable of both transmitting and listening at different intervals was the real challenge . . .

That challenge has been met and perfected by KAVCO Industries of Gardena, California with the introduction of their new KAV-COM modular ear adapter transceiver communications module.

BASIC COMPONENTS

1. **Earpiece** - custom molded from an actual cast of the *users* own ear to assure complete comfort during long hours of use as well as blocking out all unwanted ambient outside noises thus assuring quality audio reception and voice transmission unequalled by any system available to date . . .

2. **Transducer** - completely self contained micro system designed to mate instantly with the above earpiece providing all necessary electronic interface between the configurations of the users own ear and the basic two way hand held or pocket carried light-weight modern radio system.

3. **Connector** - unit provided to interface transducer wiring to actual radio unit. This may be a side screw type fastener adapter or the more common plug in type unit.

4. **Amp-Mod Unit** - this is the nerve/capsulated main control system of the KAV-COM success story: this mini/micro system, when connected to the selected hand held radio enables that radio to function in every normal mode without the KAV-COM attached, and yet, by simply attaching the KAV-COM unit to the same radio function as an entirely new concept of ultra-light, hands free, non-cumbersome communications system.

APPLICATIONS

Firefighters: If free flow airpack eliminates the mask mike, KAV-COM is now able to take up the slack. KAV—COM allows you to talk and listen independent of any other equipment being worn.

Law Enforcement (Immigration, military, commercial uses of all types conceivable); Foot patrol - no identifiable transmissions or loud audio to disclose position. Normal voice audio when transmitting. Suspect interrogation - with non-obvious push-to-talk switch. All conversations transmitted and recorded if desired. ONA calls pre-empted when necessary

Undercover - worn inconspicuously in the ear with a cord running down to radio. When supplied with under arm or sleeve cord push-to-talk switch communications can be completed with minimum interference with other essential activities.

Motorcycle officers - being totally independent of vehicle enables user to dismount and pursue on foot without interruption of vital communications link.

Paramedic/Fire Jumpers, Etc. (aviation, commercial uses): Stability and function of your communications system even when worn under crash helmet is unsurpassed. It assures continual communications even during a normally disabling landing.

KavCom

A NEW CONCEPT IN HANDS FREE VOICE COMMUNICATIONS

Transmit and
receive through
your ear.

KavCo Industries, Inc.
Sales Office: 416 East Alondra Blvd. • Gardena, CA 90248 • (818) 782-2902
Corporate Office: (213) 324-2401

KavCom allows clear voice transmission to be sent and received through the same earpiece. The transducer picks up minute sound energies from the otolarynx canal as the person speaks. These are amplified and transmitted through the users radio.

The system can be installed in virtually any VHF, UHF, or HF radio. When disconnected. the radio returns to its normal operating mode

- **EARPIECE**

  Custom molded from an actual cast of the user's ear. Assures complete comfort during long hours of use. Blocks out all unwanted ambient noises and assures unequalled audio reception and voice transmission.

- **TRANSDUCER**

  Completely self-contained micro system designed to mate with the earpiece. Provides all necessary electronic interface between the user's ear and the two way hand held or pocket carried radio.

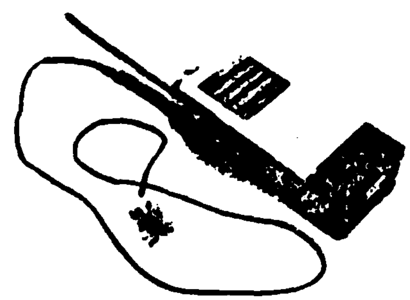
- **CONNECTOR**

  Interfaces transducer wiring to the radio. May be a side screw type fastener adapter or the more common plug-in type unit.

- **EXTENDED PUSH-TO-TALK SWITCH**

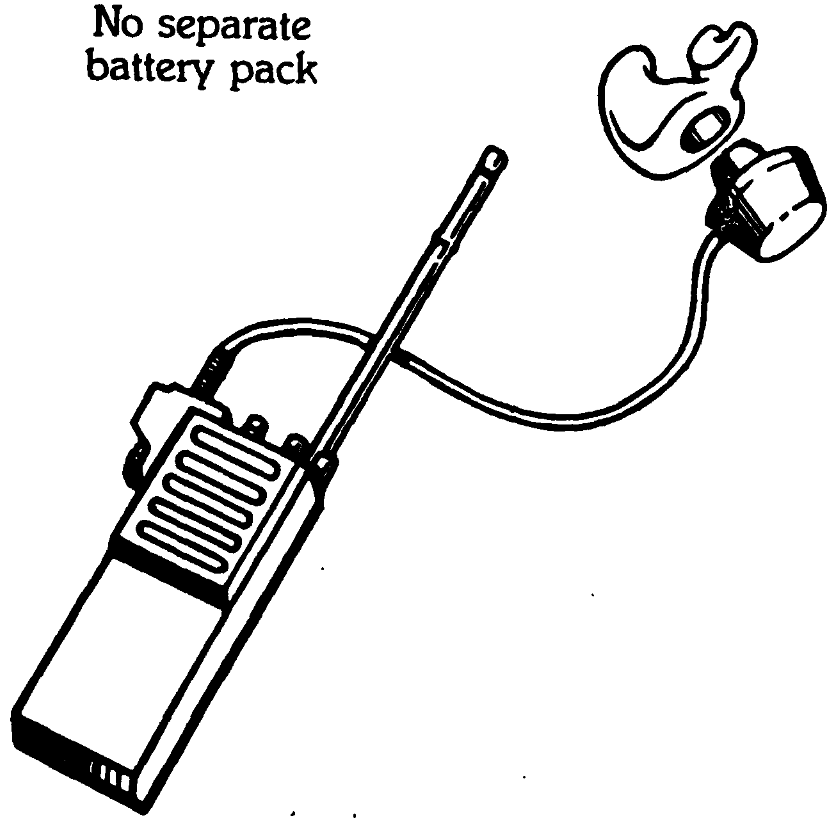
  Cord running down the arm attached to a hand switch allows hands free transmission.

- Custom designed transmitting switches available upon request.



Standard Microceiver for Uniden.

No separate battery pack



FEATURES

- Hands free operation with extended push-to-talk switch
- Custom molded earpiece snaps on & off—*Multiple* personnel can use same radio
- No feedback when units are close together
- No interference with breathing apparatus
- Radio can be used in normal mode if desired
- No separate battery pack required
- Transmits audio levels as low as a whisper
- Blocks out outside noise while receiving and transmitting
- No extra box full of electronics

APPLICATIONS

- **FIREFIGHTERS**

When the free flow airpack eliminated the mask mike, **KavCom** was there to take up the slack.... Speak or listen independently of any other equipment being worn.

- **LAW ENFORCEMENT:**

Police, Border Patrol, FBI, Secret Service, etc.

Foot Patrol - No identifiable transmissions or loud audio to disclose position. Normal voice audio when transmitting. Suspect interrogation with non-obvious push-to-talk switch. All conversations transmitted and recorded if desired.

Undercover - Worn inconspicuously in the ear with a cord running down to the radio. When supplied with under arm or sleeve cord push-to-talk switch communications can be completed with minimum interference with other essential activities.

Motorcycle Officers - Being totally independent of vehicle's radio enables user to dismount and pursue on foot without interruption of vital communications link.

- **PARAMEDICS/FIRE JUMPERS, ETC:**

Stability of system when worn under crash helmet is unsurpassed. Thus assuring continual communications even during landing, which would normally cause the system to malfunction due to shock or physical contact.

- **OTHER APPLICATIONS:**

Construction, Mining, Logging, Building Security, Airline Gate Agents, Ramp Operations or Military. Applies anywhere that 2-way voice with hands free or totally discreet communication is required. The unit is extremely valuable in a high noise environment since it muffles all outside noises.

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APPENDIX D

Study Contacts

A number of individuals and organizations provided material, insights, and recommendations that have been incorporated into this Firefighters Communication System Operational Test Plan. Among the contributing sources are:

<u>Electronic Industries Association</u>

Pete Bennett, Staff Vice-President
Washington, DC

<u>Factory Mutual Research</u>

Robert L. Martell, Jr., Manager, Instrumentation Section
Norwood, MA

<u>Federal Communications Commission</u>

Frank Coperich, Electrical Engineer
Columbia, MD

<u>National Aeronautics and Space Administration</u>

Joseph L. Bell, Electrical Engineer
NASA Marshall Space Flight Center
Huntsville, AL

<u>National Institute of Occupational Safety and Health</u>

John Etherton, Explosive Atmospheres Specialist
Morgantown, WV

<u>United States Coast Guard</u>

Lt. S. Phil Glenn, Response Officer
Mr. Lundburg, Strike Team Member
Mr. Perkins, Strike Team Member
Mr. Snyder, Strike Team Member
National Strike Force
Atlantic Strike Team
Elizabeth City, NC

Lt. JG Jeff Stull, R&D Officer Headquarters
Washington, DC

<u>United States Fire Administration</u>

Mr. Tom Smith
National Emergency Training Center
Emmitsburg, MD

OPERATION MANUAL
FOR THE
COMMUNICATIONS VEST
ENGINEERING PROTOTYPES
MODEL 6700-F12C (860120)

IMPORTANT NOTICE These eight radio assemblies have been prepared by REMIC Corporation under the terms of contract NAS8-36456, to demonstrate a communication system with certain characteristics. These units are only for conveying a concept and are not intended for use in actual situations. The final configuration remains to be determined.

January 20, 1986

PRELIMINARY INSTRUCTION MANUAL
MODEL HCPE 6700-F12C
TRANSCEIVER SYSTEM

GENERAL

The model HCPE 6700-F12C transceiver system is a self-contained two-way radio transceiver and control system. All of the system components have been integrated into a garment design to protect the unit as well as afford a system that is easy to use and operate. The number of controls have been minimized. All functions are controlled by a sealed membrane keypad. All control settings are stored in an internal memory and are recalled each time the unit is turned on. This unit is designed to operate as a stand-alone communications system or with the model HCPE 6350-F11C repeater station for added range and flexibility.

The transceiver has built in VOX (voice operated transmitter) circuitry. This mode affords the user "hands-free" operation. When the user speaks, the unit automatically switches to transmit; when the user is silent, the unit switches back to receive. This mode is extremely useful when the user's hands are not free to operate controls or switches.

Two other modes of operation are available: PTT (push-to-talk) and MONITOR.

In the PTT mode the unit will transmit only when the user presses the PTT switch. Two PTT switch options are provided. One switch is located on the keypad, the other is a remote package which can be attached to a belt or strap via a simple clip. The entire front surface of the remote PTT switch is sensitive to motion so that pressure anywhere on the switch plate will serve to activate the transmitter. The PTT mode is useful in areas of high ambient noise where unwanted transmissions sometimes result when VOX operation is attempted. The PTT mode is also useful in conserving battery life since the transmitter must be activated by the user. The PTT mode should be used when there are a large number of field units as the messages will be relayed with more efficiency.

The MONITOR mode selects a condition where the transmitter is disabled but the receiver is functional. This mode allows users to monitor conversations without the chance of disturbing communications in progress. All units not actively engaged in the communications network should use the MONITOR mode of operation.

Several microphone options can be connected to the HCPE 6700-F12C. The microphone option should be selected by the task at hand. Options include a handheld PTT microphone, a contact type throat microphone for high noise situations, and the built-in RF mask microphone system.

One of the main uses for the RF microphone system is to provide a communications link through the barrier imposed by a breathing mask (SCBA). This type of mask operates with an airtight seal around the face of the wearer so that none of the air outside of the breathing chamber can be inhaled by the wearer. This type of physical arrangement likewise does not allow air from the inside of the breathing chamber to reach the outside of the mask unless it passes through a check valve system. The construction of the mask makes the wearer's speech inaudible or muffled. Attempts have been made to solve this communications problem by passing microphone cables through the rubber membrane material of the mask. This solution is not acceptable as the air tight integrity of the mask cannot be guaranteed. Mask manufacturers will not honor claims on any equipment that has been modified in this manner. Several other pass-through systems have been certified, however, these cannot be retrofitted to existing masks in the field. After-market products using magetic induction (transformer action) principles have been offered, but have several disadvantages among which are:

1. Hum or noise in the signal

2. Large size

3. Require a battery powered circuit inside the mask.

These limitations offer serious problems to the users of these microphone devices. The hum or noise present in the signal can cause serious problems in understanding speech that is already distorted by the wearing of the mask itself. Large component size limits the placement of the microphone to an area that might not be optimized for the best speech reproduction or pick-up. Many problems result from the internal (to the mask) battery location. Breathing equipment and masks are usually used in situations of life-threatening complexity. The wearer cannot be assumed to be mindful of the battery condition of his mask microphone system at all times - especially at the conclusion of his tasks. Forgetting to turn off or recharge the internal mask microphone system will deplete the batteries and render the device useless the next time its use is attempted. This is further aggravated by the lack of availability of the special batteries typically used in these systems.

The REMIC RF microphone system addresses all of the above-mentioned deficiencies. Micro-power circuitry coupled with RF technology permits a system to be built with the following advantages:

1. Small size internal circuitry

2. High quality audio reproduction

3. No internal batteries or switches

4. Easy installation on most commercial masks

The RF microphone system is composed of two main component parts; the driver assembly and the responder assembly. The driver assembly affixed to the outside of the mask, usually on the facepiece where it will not affect vision. The responder is mounted wherever space permits on the inside of the mask. The RF coil of the responder is mounted to the facepiece opposite to the driver RF coil. The microphone is then located where it will pick up speech in the clearest manner. These components can be permanently fixed in position. All system power is provided by the transceiver battery.

An inline connector allows the driver to be separated from transceiver so that the mask can be easily stored. The responder circuitry is fully encapsulated so that the mask can be cleaned without the need to remove any internal component.

The transceiver is supplied with a clip mounted antenna holder. This holder is designed to be easily attached to the rear lip of any common hard-hat or helmet. The antenna is connected directly to the clip mount. The mounting is such that the antenna is positioned vertically at the rear of the head. This position has been determined to be the best for propagation of radio waves. Mounting the antenna near to metal assemblies (of the SCBA) or close to the body will detune the antenna and decrease its efficiency and the range of the system.

THE TRANSCEIVER SHOULD NEVER BE OPERATED WITHOUT THE ANTENNA CONNECTED AND IN PLACE.

Receiver audio is provided by two water resistant speakers mounted in the transceiver garment. These speakers present the receiver audio close to the user's ears eliminating the need for earphones. Receiver volume is controlled in four steps by the volume control button.

The entire transceiver assembly is easily and quickly donned. The unit is put around the neck and the straps adjusted for comfortable yet adequate support of the unit. The unit can then be removed by unsnapping the button type snaps - without disturbing the strap adjustments. Additional support is available if required by attaching the back strap assembly.

CONNECTORS

ANTENNA: A BNC plug is provided to mate with the socket on the clip mount bracket. The antenna is mounted to the top socket on the clip mount; the transceiver cable to the bottom socket. The connectors are engaged with a slight forward pressure and turned 1/4 turn to lock them into place.

MICROPHONE: A polarized 9 pin connector is provided for attachment of the various microphone options. The two halves (transceiver and microphone) are aligned and pressed together. This connector is not a locking type. A measure of safety is provided in the rare instance that the user become tangled in the cords - the connector will simply pull apart with no damage to the transceiver or user.

CHARGER/PTT: A polarized pigtail connector attached to the control unit serves to connect either the remote PTT (push-to-talk) switch OR the battery charger. The connector halves are aligned and pressed together until they lock. They are released by pressing the small locking button and pulling apart.

CONTROLS:

All operational controls are located on the side of the control assembly and are activated by pressing the appropriate membrane switch. The switches are sealed and waterproof. Control response is verified by LED indicators which are visable on the front of the unit. Important mode and channel settings are always displayed when the unit is in operation.

ON/OFF: Applies power to the transceiver circuitry. When turned ON, the unit will activate with all of the settings that were programmed when it was last used. Turning the unit OFF will store the last entered control settings. These settings are erased if the battery is removed or allowed to discharge completely. In this case, the unit will always turn ON in the DIRECT and MONITOR modes.

CHANNEL: Switches the transceiver circuitry between DIRECT or REPEATER modes of communication. In the DIRECT mode, the transceiver is configured so that it will communicate directly with other transceivers (without the repeater). Field units will talk directly to field units. The DIRECT LED will illuminate when the DIRECT mode is selected. The REPEATER mode configures the transceiver so that it will access the repeater station. In this mode direct communications between field units are not possible, this communication link is relayed through the repeater station. The repeater station must be in operation for units to communicate in the REPEATER mode. The REPEATER LED will illuminate when the REPEATER mode is selected.

MODE: Selects one of the three main operation modes: VOX (voice operated, hands-free) PTT (push-to-talk), or MONITOR. The appropriate LED will be illuminated to display the mode selected.

VOLUME: Selects one of the four preset volume levels for the receiver audio. Pressing the switch will cause the levels to cycle through all four settings and return again.

PTT: Unit mounted push-to-talk switch which is enabled in the PTT mode. This switch parallels the operation of the remote PTT switch.

SET-UP AND OPERATION

1. Assemble your choice of options based on headgear, breathing apparatus and protective clothing. These options include the microphone type and remote PTT switch if required.

2. Don the transceiver unit and adjust for comfortable fit. Make sure that the transceiver unit does not interfere with any ensemble system and that the transceiver will not be damaged by other straps and fittings.

3. Fit the clip mount antenna clamp to the headgear and connect the antenna to the top of the clip mount and the transceiver cable to the bottom of the clip mount. The antenna should be vertical and clear of all obstructions. It should never come in contact with a metal assembly and it should be located away from the body. NEVER OPERATE THE TRANSCEIVER WITHOUT THE ANTENNA CONNECTED.

4. Attach the remote PTT switch if required. The switch plugs into the pigtail connector at the bottom of the control unit and locks into place. Locate the PTT assembly where it is accessible and where it will not be activated by a component of the protective clothing pressing on it.

5. Connect the microphone to the microphone connector. Orient or place the microphone in its required operating position.

6. Activate the unit by pressing the ON/OFF switch. The front panel LEDs will illuminate displaying the stored operational modes.

7. Determine the required operating conditions. Select the channel of operation: DIRECT or REPEATER; the mode: VOX, PTT or MONITOR; and adjust the receiver volume.

8. The unit may be deactivated if other tasks require the user's attention (such as further dressing, etc.) since the operating selections are now stored in memory. These will be preset by simply turning the unit on with the ON/OFF switch.

9. During use, transmissions should be as direct and as short as possible in order to conserve battery life. This is particularly true if operating in the VOX mode. Keep in mind that ANY sound - grunts, groans, off-hand comments, four letter words - will activate your transmitter. If you transmit while others are communicating, your transmission could interrupt all transmissions on the channel causing others to miss segments of their message. The VOX mode should be used with utmost discipline and where the PTT mode is not practical.

10. After use, turn the unit OFF and carefully disconnect the microphone, remote PTT switch and antenna. Inspect the unit and clean any parts that have become contaminated. If the unit is wet, store it where moisture can evaporate. Clean the fabric with soap and water. Remove dirt from the connectors with a small brush and low pressure compressed air. Never submerge the transceiver unit.

11. After the unit has been cleaned, attach the battery charger to recharge the internal batteries. The charger is plugged into a standard 110 VAC outlet. The charger connector is plugged into the pigtail connector at the bottom of the control unit. The batteries require 12 to 16 hours to completely recharge.

12. Inspect and clean accessories.

PRELIMINARY SPECIFICATIONS
TRANSCEIVER SYSTEM
MODEL HCPE 6700-F12C

Housing:	Self-contained vest
Environmental rating:	Splash-proof
Size:	
Weight:	
Power requirement:	Internal rechargeable battery
Duty cycle:	2 hours (10% transmit: 10% receive; 80% standby)
Battery recharge:	12 to 16 hours
Antenna type:	Flexible, rubber coated
Microphone type:	RF mask mic PTT handheld Throat (contact) type
Transmitter power output:	2 watts
Transmitter frequency:	157.075 MHz (DIRECT mode) 150.980 MHz (REPEATER mode)
Receiver frequency:	157.075 MHz
Audio power output:	0.5 watts
Speaker type:	Mylar cone. Two units.
Electronic specifications:	Per FCC & EIA

OPERATION MANUAL
FOR THE
REPEATER STATION
ENGINEERING PROTOTYPES
MODEL HCPE 6350-F11C

IMPORTANT NOTICE These four repeater stations have been prepared by REMIC Corporation under the terms of contract NAS8-36456, to demonstrate a communication system with certain characteristics. These units are only for conveying a concept and are not intended for use in actual situations. The final configuration remains to be determined.

January 20, 1986

PRELIMINARY INSTRUCTION MANUAL
REPEATER STATION
MODEL: HCPE 6350-F11C

General:

The model HCPE 6350-F11C repeater station is a completely self-contained unit primarily used to increase the range and coverage of a two way communications system. The repeater operation is completely automatic and requires no adjustment after initial set-up. This unit can operate from a variety of common power sources and also contains a built-in battery for field operations where no power is available. All system components are housed within the rugged aluminum case for ease of transport to the site of operations.

A repeater station can increase the range and coverage of two-way radio signals in the following manner. Power output limitations on portable transceivers often result in poor or uneven communications in areas where natural terrain variations impede the propagation of the radio waves. Likewise, structures and buildings cause similar problems. The repeater station solves these problems by acting as a relay station between units using radio communication. The placement of the repeater is critical to the effectiveness of the device. The repeater should be located as near as possible to the feature causing the communications problem. For example, if the field site is outdoors and a hill or bluff separates the two units requiring communications, the repeater should be located at the crest of the hill so that signals from either unit can access the device. In the case of a man-made structure, the repeater should be located at some logical interface, such as a doorway, so that units inside and outside of the structure can access the device. Some experimentation will be required to find a location that serves all units to the best advantage.

A repeater operates by receiving a signal on its input frequency and retransmitting the signal on its output frequency. In this process, the signal may be retransmitted at a higher power level. Radio transceivers must be specially equipped to interface with repeater stations. Their transmitters and receivers must be configured with the proper frequencies required by the repeater. The operation of the radio transceivers is not affected by repeater operation.

OPERATION AND MAINTENANCE

1. Unpacking: Remove the front case section by unclamping the six clasps located around the seam in the case. This seam contains a gasket for sealing the case parts; care should be taken not to damage the surfaces. The front case section contains the flexible antenna which is secured by a set of clips. Remove the antenna from the clips and connect it to the antenna connector on the top of the unit. Place the front case section where it will not be damaged or misplaced.

2. Connectors:

ANTENNA: A BNC type connector for the antenna is located on the top of the repeater cabinet. The portable antenna is installed by aligning the connector parts and turning the antenna connector locking ring 1/4 turn. The antenna will be locked into position. A remote antenna may be used in place of the portable antenna; it must have a BNC connector for correct attachment.

DO NOT ATTEMPT TO USE OTHER TYPES OF CONNECTORS.

The antenna should be connected before any power is applied to the unit or the unit is operated from its internal battery.

POWER: External power for operating the repeater is supplied through this connector. Power sources include the AC power supply and battery charger; the 12 VDC power cord; and the 24 VDC power cord. This connector is keyed so that the connectors can only be inserted one way. Do not force connectors together. When correctly aligned the connector requires a slight forward pressure while turning clockwise 1/4 turn. When correctly installed the connector will be locked into position.

MIC/HEADSET: This connector interfaces either the handheld microphone or the headset/boom microphone to the repeater. No connections are required if the unit is to be operated in the REPEAT mode only and an operator will not be on hand. The installation of this connector is identical to that of the power connector.

Controls:

POWER: The power switch controls the operation of all functions except charging of the internal batteris. With the power switch in the OFF position, no operation is possible. With the switch in the ON position, operation is determined by the REPEAT/LOCAL switch setting. A red LED is illuminated when the power switch is in the ON position. This light will not illuminate if the power source is incorrectly connected or the internal batteries are exhausted. The power switch should be turned OFF to conserve the batteries when the unit is not being used.

REPEAT/LOCAL: This switch controls the automatic functions of the repeater. In the REPEAT positions, the repeater will automatically retransmit the signals it receives. When an input signal is present, the transmitter will automatically be enabled. The transmitter will remain on for the duration of the incoming message and will be disabled after the message is complete. The transmitter action is displayed by the LED labeled TRANSMIT. Conversations may be monitored by the built-in loudspeaker or on the headset. In the LOCAL position, messages are received by the unit, but are NOT repeated. The unit can be used as an operator controlled base station with the operator responding to messages using the push-to-talk (PTT) microphone or boom microphone. The transmitter will only be enabled when the PTT switch is pressed. LOCAL operation implies that the messages from users of the system will NOT be heard by each other as they are in the REPEAT mode. The LOCAL mode is provided for situations when units are under the sole direction of the station operator, or when a monitor only function is desired.

SPEAKER: A switch is provided to disable the internal loudspeaker. The speaker should be turned OFF when the unit is in operation and no monitoring is required (extends battery life). The speaker can also be disabled when local security is desired and the headset is being used for monitoring.

VOLUME: A rotary control is provided to control the audio volume of the loudspeaker and in the earphones of the headset.

SET-UP AND OPERATION

1. Locate the repeater in a logical position. Typically an elevated location is preferred as the lines of propagation to and from the repeater are less likely to be obstructed. The unit should not be located close to sources of heat or near operating machinery that could cause electrical interference. The unit should be located so that its antenna is free and clear of metal objects as the metal will distort the radio waves.

2. Unpack the unit as detailed earlier and connect the antenna to the unit BEFORE any other operation.

3. Select a power source. If the field operation is in an area that has 110 volt power available, it is best to use the AC power supply. If AC power is not available, the internal batteries or other DC power can be used. Field operations of long duration will require that an external battery such as an automobile battery be used. The internal battery will provide operation for a minimum of 4 hours. Connect the unit to the appropriate power source.

4. Activate the unit by moving the POWER switch to the ON position.

5. Select the mode of operation: REPEAT or LOCAL.

6. Set the SPEAKER switch to the ON position and rotate the VOLUME control 1/3 turn clockwise from its minimum setting.

7. Connect the PTT microphone.

8. Establish contact with field units to insure that all units can transmit to and receive from the repeater. Relocate the repeater if field units experience difficulty in communicating through the system.

9. If local monitoring is NOT required, move the SPEAKER switch to the OFF position.

10. The repeater will operate unattended until disabled.

11. If the repeater operator needs to communicate with the field units, he may do so at any time by using the PTT microphone. The repeater operator will take precedence over any communications in progress - his transmission will mute the messages from field units - only as long as the PTT microphone is used. It is not necessary to change any repeater settings to use the PTT microphone.

12. When the field operation is completed, move the mode switch to the LOCAL position and the POWER switch to the OFF position.

13. The unit should be cleaned if it has been subjected to harsh environmental conditions. Low pressure compressed air can be used to remove dirt and dust around the controls and connectors. The case should be cleaned with soap and water. The unit should never be submerged.

14. The internal batteries should be recharged after every use. The recharing is accomplished automatically each time the unit is connected to the AC power supply unit. The unit should be stored with the AC power supply connected and turned ON to maintain fully charged batteries. NOTE: The internal batteries are NOT depleted if the unit is used on an external power source.

15. The unit may be operated continuously from the AC power supply.

The repeater station may be connected to a remote vehicular or base station antenna if permanent or mobile operation is dictated. Please check with REMIC regarding specific antenna requirements before connecting any antenna other than the one supplied with this unit.

PRELIMINARY SPECIFICATIONS
REPEATER STATION
MODEL HCPE 6350-F11C

Housing:	Aluminum
Environmental rating:	Splash-proof; weather resistant
Size:	
Weight:	
Power requirements:	110 VAC external power supply 12 VDC; 1.5A 24 VDC; 1.5A Internal sealed battery
Duty cycle:	Continuous from remote power 4 hours minimum from internal battery
Battery recharge:	Automatic using 110 VAC supply
Antenna type:	Flexible, rubber coated, connector mounted Remote vehicular or base station
Microphone:	Noise canceling with PTT switch Headset/boom microphone with PTT switch
Speaker:	Reflex horn type, waterproof
Transmitter power output	4 watts
Transmitter frequency:	157.075 MHz
Receiver frequency:	150.980 MHz
Audio power output:	4 watts

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